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# RESOURCE RECOVERY AND SOURCE REDUCTION

## FIRST REPORT TO CONGRESS

ENVIRONMENTAL PROTECTION AGENCY

1974

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# RESOURCE RECOVERY and SOURCE REDUCTION

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The findings of this report are based on a number of contractual efforts and analyses by the Agency staff performed since the passage of the Resource Recovery Act.

The report is organized into a summary, four major sections, and two appendixes. The first section discusses the problem to which resource recovery is the potential solution. Next, key findings related to resource recovery are presented. A section outlining major options follows. The report concludes with a discussion of EPA's program activities in resource recovery.

The appendix presents summaries of information about the status of resource recovery, according to material categories and lists existing resource recovery facilities.

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# FIRST REPORT TO CONGRESS
# RESOURCE RECOVERY and SOURCE REDUCTION

*This is the third edition of the report (SW-118) prepared by the OFFICE OF SOLID WASTE MANAGEMENT PROGRAMS, as required by Section 205 of the Solid Waste Disposal Act as amended, and was delivered February 22, 1973, to the President and the Congress.*

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# FOREWORD

Section 205 of the Solid Waste Disposal Act (Public Law 89-272) as amended requires the U.S. Environmental Protection Agency (EPA) to undertake an investigation and study of resource recovery. This document, which represents EPA's Report to the President and the Congress, summarizes the Agency's investigations to date and reports on the manner in which the congressional mandate is being performed.

The findings of this report are based on a number of contractual efforts and analyses by the Agency staff performed since the passage of the Resource Recovery Act. Extremely valuable assistance in these investigations has been provided by the Council on Environmental Quality.

The report is organized into a summary, four major sections, and two appendixes. The first section discusses the problem to which resource recovery is the potential solution. Next, key findings related to resource recovery are presented. A section outlining major options follows. The report concludes with a discussion of EPA's program activities in resource recovery.

The appendix presents summaries of information about the status of resource recovery, according to material categories and lists existing resource recovery facilities.

Although there have been minor editorial revisions, this publication is essentially the same as that delivered to the Congress. A number of typographical errors that appeared in the first printing have been corrected, the references have been restyled, and the report has been typeset in a conventional style to improve its readability.

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*Deputy Assistant Administrator*
*for Solid Waste Management*

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# SUMMARY


This report explores resource recovery as a method of solid waste management and resource conservation. Information gathered over the past several years is summarized, and the many issues raised by the complex subject of resource recovery are discussed.

The emphasis of the report is on the recovery of materials and energy from mixed municipal wastes and other "postconsumer" wastes that are discarded and accumulate outside normal waste collection channels. Although they represent only 5 percent of the total national solid waste load, these wastes tend to have the most frequent, immediate, and apparent impact because they occur in the Nation's urban areas. More than 50 percent of the total waste load comes from agriculture and is usually returned to the soil. More than 40 percent of the total burden is mining waste, which occurs in the hinterland.

Nearly all major materials are recovered to some extent by recycling. Most recovered materials result from industrial fabrication wastes. Postconsumer wastes, waste paper, old automobiles are also recovered to some extent. postconsumer recycling has grown in an absolute sense. However, the proportion of the Nation's material requirements satisfied by recycled materials has either remained constant or has declined in most instances.

The level of recycling depends almost entirely on economics. Recycling takes place to the extent that it is the most efficient use of resources. More secondary or recycled materials would be used if economic subsidies for "natural" or "virgin" materials were not provided. The economics of recycling are also influenced by apparently inequitable freight rates both ocean and rail which make the transportation of secondary materials relatively more costly than the movement of virgin resources.

Sufficient technology has been developed to extract materials and energy from mixed municipal wastes. However, few full-scale recovery plants exist. The U.S. Environmental Protection Agency is funding demonstrations of the most significant conceptual alternatives.

The costs of recovery plants are estimated to be relatively high, making recovery by technological means attractive only in areas where high disposal costs prevail and local markets for waste materials exist. There is evidence that recovery by separate collection is not only feasible but economically attractive provided that the collection utilizes an existing transport system and markets for the collected materials exist.

Preliminary research and analysis indicate that compared with virgin material extraction and processing, resource recovery results in less atmospheric emissions, waterbourne wastes, mining and solid wastes, and energy consumption. There is substantial disagreement among experts about the extent of such differential effects over time, particularly as stronger environmental constraints on use of both virgin and secondary materials begin to narrow the current differentials.

Recycling should become more economical relative to other solid waste disposal options during the next several years. Energy costs are rising, making energy recovery more attractive and more economical. As pressures to bring about environmentally sound waste disposal increase, disposal costs will rise, and recovery will become a more attractive alternative. Finally, to the extent that air and water pollution control regulations are strengthened, the industrial incentives for using secondary materials will improve.

Other incentives for recycling exist under present Federal policies. The General Services Administration does not purchase paper unless it contains a specified proportion of recycled paper. The military services are exploring procurement policies




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to reduce waste quantities or to require the inclusion of secondary materials. The Treasury Department has determined that tax-exempt industrial revenue bonds may be used to finance the construction of recycling facilities built by private concerns to recycle their own wastes.

Additional Federal incentives for recycling are not considered desirable at this time. Studies to date indicate that the effectiveness of specific incentive mechanisms that can be formulated is extremely difficult to predict. New tax incentives may well distort the economics of resource utilization much as preferential treatment of virgin materials distorts them today.

There is an obvious need to explore further the complex issues of material utilization in the United States in the context of total resource utilization. Resource recovery is an important part, but only one part, of the larger picture. Before additional Federal policies are developed—aimed possibly at overcoming institutional and market imperfections in some areas—a better understanding of the complex material and energy situation must be gained.

# FIRST REPORT TO CONGRESS ON
# RESOURCE RECOVERY and SOURCE REDUCTION

## 1. THE PROBLEM

### U.S. MATERIAL-USE PATTERN

Resource recovery in its various aspects must be seen as part of a much larger economic structure – the total material- and energy-use patterns of the Nation. The recovery of waste materials today supplies only a very small part of the total material and energy requirements of the U.S. population. Moreover, although both population and material consumption are increasing, the use of materials from waste sources is declining relative to overall consumption.

In 1971, the U.S. economy used an estimated 5.8 billion tons of materials for its total activity, equivalent to 28 tons for each man, woman, and child. Of this total, approximately 10 percent came from agriculture, forestry, fishing, and animal husbandry (food and forest products); 34 percent was represented by fuels; 55 percent came from the mineral industries in the form of construction materials, metals, and other minerals.[1]

Material use is growing at a rate of 4 to 5 percent yearly. Per capita consumption was 22 tons in 1965, 24.7 tons in 1968, and 28 tons in 1971.[1] During the same period, population grew at an annual rate of 1.3 percent.

A high rate of material and energy consumption means a high rate of waste generation. Approximately 10 to 15 percent of the annual input to the economy accumulates as materials in use (in structures, plants, equipment, etc.). The rest of the tonnage is used consumptively, with residues discharged to the land, water, and air, or is used to replace obsolete products and structures, which in turn become waste.[2]

Nearly all the materials and energy required in the United States come from virgin or natural resources. The tonnage of fabrication and obsolete wastes recycled is approximately 55 to 60 million tons, equivalent to less than 1 percent of total mineral tonnage required by the Nation.[3]

If we disregard food and energy substances, the estimated 1971 demand for nonfood, nonenergy materials was 3.6 billion tons; waste recovery satisfied 1.5 to 1.7 percent of this total requirement.

### ENVIRONMENTAL CONSEQUENCES OF MATERIAL USE

All forms of material use have environmental consequences. Material resources must be extracted, purified, upgraded, processed, and fabricated into products; in addition, transport is necessary between most of these steps. Solid, waterborne, and airborne wastes are generated at every point and either enter the environment or are removed during processing at some expense.

The production of 1,000 tons of steel, for instance, results in 2,800 tons of mine wastes, 121 tons of air pollutants, and 970 tons of solid wastes.[4] Similar waste flows are associated with every material flow, although the magnitude varies, depending on the particular material. The sheer growth in per capita material consumption indicates that more pollution and waste is generated per capita today than was generated in the past.

As will be discussed, reports at this time indicate that the amount of air pollution, water pollution, and solid waste that results from production systems using recycled wastes is lower than the effluents from production systems relying on virgin

resources. Thus, any decrease in resource recovery relative to total consumption means an increase in the quantity of residuals generated.

## SOLID WASTE GENERATION

Ever-increasing per capita material consumption necessarily means that more solid waste is generated. This is illustrated graphically by trends in packaging consumption, because packaging is a short-lived product that becomes waste immediately after use. Per capita packaging consumption (in pounds per capita) has been increasing steadily as shown below:[5]

| 1958 | 1960 | 1962 | 1964 | 1966 | 1970 |
|---|---|---|---|---|---|
| 404 | 425 | 450 | 475 | 525 | 577 |

The situation in packaging is merely an illustration of the general phenomenon that arises because the material consumption rate grows faster than population.

The total quantity of waste generated in 1971 is estimated to have been 4.45 billion tons, up nearly 1 billion tons from 1967. The makeup of this waste is shown below.

| Sources of waste | Volume of waste (Millions of tons) |
|---|---|
| Municipal[6,7]* | 230 |
| Industrial[8] | 140 |
| Mineral[9,10] | 1,700 |
| Animal[11,12] | 1,740 |
| Crop[11,12] | 640 |
| Total | 4,450 |

*Municipal wastes include residential, commercial, demolition, street and alley sweepings, and miscellaneous (e.g., sludge disposal).

The 230-million-ton municipal waste load plus that portion of industrial waste occurring in large metropolitan areas constitute what is normally referred to as the "solid waste problem" in popular discussion.

One reason for the growing solid waste burden is that resource recovery has declined relative to total material consumption. A second reason is the substitution of material-intensive practices (practices that result in consumption of large amounts of raw materials) for practices that are less material demanding, e.g., one-way containers for returnable bottles, paper towels for cloth towels, and disposable one-time-use products of all sorts in the home, the office, the hospital, etc., for products designed for reuse.

The resulting solid waste load is especially burdensome in urban areas because of greater population concentrations and because disposal in urban areas is particularly difficult. The urban population, for example, has grown from 64 percent of the total population in 1950 to 74 percent in 1970, thereby increasing the quantity of solid waste in urban areas by a substantial percentage. Additionally, urban populations generate more waste than nonurban residents--approximately 20 percent more per capita.[13]

Disposal in urban areas is an especially difficult problem because waste disposal in the city is, at the same time, an environmental, an economic, and a political problem. Waste collection is labor intensive; labor costs are rising rapidly; and the productivity of most municipal waste collection systems is low. In many urban areas, land suitable for waste disposal has disappeared or is rapidly being used up. Movement of the waste across the boundaries of the political jurisdiction where it is generated is difficult and, sometimes, impossible. When cities are required to move their wastes over greater distances to dispose of them or, alternatively, are forced to process them to achieve volume reduction, the costs of waste management are increased. To eliminate potential air and water pollution from landfills and incinerators, waste-processing facilities must be properly designed, located, and operated, and they must include proper pollution control devices. This degree of control is technologically feasible but often costly, particularly in the case of incineration.

Given these circumstances, many cities are increasingly viewing resource recovery as both an environmentally and an economically desirable alternative to disposal. Unfortunately, this option is most often not available because demand for materials from wastes is nonexistent or severely limited.

## THE RECOVERY RATE

Nearly all major materials are recovered to some extent by recycling. The recovery rate varies

from nearly 100 percent for solid lead (50 percent for all lead),* 50 percent for copper, 31 percent for iron and steel, and 19 percent for paper and board, to 4.7 percent for glass (Table 1). These percentages refer to the proportion of total material consumption satisfied from both wastes recovered in fabrication steps in industry and wastes recovered from obsolete products like junk automobiles and old newspapers.

Consumption of major materials - iron and steel, paper, nonferrous metals, glass, textiles, and rubber--took place at a rate of 190 million tons in the 1967-68 period. During this period, the total recycling tonnage of the same materials was 48 million tons, equivalent to 25 percent of consumption of these materials.

Historical data in this aggregated form are not available for all materials. For most materials in general, however, the portion of the total consumption derived from waste sources has been declining. Consumption of these waste materials has generally not kept pace with total consumption.

Paper waste consumption as a percent of total fiber consumption has declined from 23.1 percent in 1960 to 17.8 percent in 1969.[14]

Iron and steel scrap consumption as a percent of total metallics consumption declined slightly overall from the 1959-63 to the 1964-68 period from 50.3 to 49.9 percent. Purchased scrap consumption,* representing the recycling of fabrication and obsolete wastes, has been losing gound: in the 1949-53 period it was 44.9 percent of total scrap; in the 1964-68 period, 40.0 percent.[15]

*A substantial proportion of lead is used in gasoline as an antiknock additive; this lead is dispersed and is unrecoverable.

*In the iron and steel industry, distinctions are made between "home" scrap, a process waste in furnaces and mills, "prompt" scrap, which occurs in fabrication plants; and "obsolete" scrap from discarded products or obsolete structures. "Purchased" scrap is the combination of the last two categories.

TABLE 1

RECYCLING OF MAJOR MATERIALS IN 1967*

| Material | Total consumption (million of tons) | Total recycled (million of tons) | Recycling as percent of consumption |
|---|---|---|---|
| Paper | 53.110 | 10.124 | 19.0 |
| Iron and steel | 105.900 | 33.100 | 31.2 |
| Aluminum | 4.009 | .733 | 18.3 |
| Copper | 2.913 | 1.447 | 49.7 |
| Lead | 1.261 | .625 | 49.6 |
| Zinc | 1.592 | .201 | 12.6 |
| Glass | 12.820 | .600 | 4.7 |
| Textiles | 5.672 | .246 | 4.3 |
| Rubber | 3.943 | 1.032 | 26.2 |
| Total | 191.220 | 48.108 | 25.2 |

*Source: Darnay, A., and W. E. Franklin, Salvage markets for materials in solid wastes, Washington, U.S. Government Printing Office, 1972, p.xvii.

Rubber reclaiming is a declining activity both absolutely and in relation to total rubber consumption. In 1958, reclaim consumption was 19 percent of total rubber consumption, in 1969, 8.8 percent.[16]

The major nonferrous metals—aluminum, copper, and lead—are reused at a composite rate of about 35 percent of total consumption, and this percentage has remained fairly constant over time.[17]

Historical data on other materials are not readily available in aggregate form, but declining recovery is generally the rule.

It is reasonable to assume that a secondary material, one that has already been processed, should be a more attractive raw material to industry than a virgin material that must be extracted or harvested and processed. The secondary material is already purified and concentrated. Scrap steel, for instance, is nearly 100 percent steel, while the iron ore from which it is made contains large proportions of silicate materials, which must be removed.

The low recycling rate is the result of a number of factors, among them the following:

(1) The delivery price of virgin raw materials to the manufacturer is almost as low in many cases as the cost of secondary materials, and virgin materials are usually qualitatively superior to salvaged materials. Consequently, demand for secondary materials is limited.

(2) Natural resources are abundant, and manufacturing industries have directed their operations toward exploiting them. Plants are generally built near the source of virgin materials (e.g., paper plants near pulpwood supplies). Technology for utilizing virgin materials has been perfected; because of adverse economics similar technology to exploit wastes has not been developed.

(3) Natural resources occur in concentrated form, whereas wastes occur in a dispersed manner. Consequently, acquisition of wastes for recycling is costly and is particularly sensitive to high transportation costs.

(4) Virgin materials, even in unprocessed form, tend to be more homogeneous in composition than waste materials, and sorting and upgrading mixed wastes is costly.

(5) The advent of synthetic materials made from hydrocarbons and their combination with natural materials cause contamination of the latter, thereby limiting their recovery. The synthetics themselves are virtually impossible to sort and recover economically from mixed waste.

(6) There are artificial economic barriers that favor the use of virgin materials over secondary materials. For example, depletion allowances, favorable capital gains treatments, and apparently favorable freight rates are available to processors of virgin materials but not to secondary material processors. Also, producers presently do not have to internalize all the costs of environmental pollution.

# 2. KEY FINDINGS

The key findings of this report can be reduced to four major points:

(1) The use of recycled materials appears to result in a reduction in atmospheric emissions, generated waste and energy consumption levels, when compared with virgin material utilization.

(2) The recovery of materials from waste depends largely on economics. The cost of manufacturing products from secondary materials is generally as high or higher than that of manufacturing products from virgin materials: consequently, only high-quality and readily accessible waste materials can find a market. Artificial economic advantages available to users of virgin materials (e.g., depletion allowances, capital gains treatments, and inability of the traditional market to internalize pollution and resource depletion costs) appear to have been major contributors to this economic situation.

(3) There has been sufficient technology developed to allow materials to be extracted from mixed municipal wastes. However, the cost of extraction is high, making recovery processes attractive only in areas where high disposal costs prevail and favorable local markets exist for the materials.

(4) Recovery of materials (as opposed to energy) from mixed municipal wastes, while conceptually the best alternative to disposal, cannot be instituted on a large scale without a substantial reduction in processing costs and/or upgrading in quality (which is simply unattainable given reasonable projection of technology) and/or a major reordering in the relative prices of virgin and secondary materials, so that secondary materials become economically more attractive.

A more detailed discussion of each of these findings follows.

## ENVIRONMENTAL IMPACTS

The environmental impacts of recycling are of major importance. Studies conducted to date indicate that resource recovery generally results in reduced energy and material consumption and reduced effects of air and water pollution.

Resource recovery has three major environmental benefits: (1) recovery and reuse of a material conserves the natural resources from which that material is derived; (2) recycling of materials eliminates disposal; thus, the negative environmental effects of inadequately controlled solid waste disposal are reduced; (3) substitution of waste materials for virgin materials in the production system results in decreased energy requirements and less air and water effluents (based on studies of glass, paper, and ferrous metals) and avoids other kinds of environmental degradation, particularly in the extraction phase (e.g., strip mining). Data to substantiate these points are presented next.

### *Glass*

Environmental impacts occur at every step of glass manufacturing, from the mining of raw materials to final waste disposal. Changes in the amount of cullet (glass scrap) in the raw material batch are responsible for significant changes in environmental effects.

Comparing the environmental impact of glass manufacturing using 15- and 60-percent cullet mixes, it is clear that increased cullet usage results in reduced quantities of residual discharge. Table 2 illustrates the difference in impact for the two cullet mixes. A 60-percent cullet batch would result in over 50

TABLE 2

SUMMARY OF CULLET-DEPENDENT ENVIRONMENTAL IMPACTS FOR 1,000 TONS OF GLASS CONTAINERS, BY IMPACT CATEGORY*

| Environmental impact | 15% Cullet | 60% Cullet | Change† (%) |
|---|---|---|---|
| Mining wastes | 104 tons | 22 tons | -79 |
| Atmospheric emissions (all sources) | 13.9 tons | 13 tons<br>§10.9 tons | -6‡<br>-22§ |
| Water consumption (intake minus discharge) | 200,000 gal | 100,000 gal | -50 |
| Energy use | $16,150 \times 10^6$ Btu | $16,750 \times 10^6$ Btu<br>$15,175 \times 10^6$ Btu | 3‡<br>-6§ |
| Virgin raw material consumption | 1,100 tons | 500 tons | -54 |
| Net postconsumer | 1,000 tons | 450 tons | -55¶ |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

†Negative number represents a decrease in that category resulting from increased recycling.

‡Calculated for the Black-Clawson wet recovery system for recovery of cullet from municipal waste.

§Calculated for the Bureau of Mines incinerator residue recovery system for cullet recovery from municipal waste.

¶Based primarily on surveys conducted in 1967-1969.

percent less mining and postconsumer waste, 50 percent less water consumption, and up to 22 percent less atmospheric emissions. The energy requirements either increase by 3 percent or decrease by 6 percent, depending on the recovery system used for obtaining the cullet.

*Paper*

There are significant changes in environmental impact when wastepaper is substituted for virgin woodpulp in the production of paper products. Table 3 summarizes the environmental impacts resulting from the manufacture of 1,000 tons of pulp from recycled fiber rather than from virgin woodpulp. The use of recycled fiber requires 61 percent less process water and consumes 70 percent less energy.

Although deinking and bleaching may be required to upgrade secondary fibers for high-quality finished products, recycling still produces environmental benefits in almost every category. Table 4, which compares virgin pulp with recycled, deinked pulp, indicates that 15 percent less water and 60 percent less energy are required and that 60 percent less air pollutants are generated. However, waterborne wastes increase significantly. The increase in solid wastes generated in processing is more than offset by the recovery of paper from municipal solid waste.

*Ferrous Metals*

There are also substantial differences in environmental impact when recycled steel is utilized as opposed to steel produced from iron ore. A comparison of the impacts of producing 1,000 tons of steel reinforcing bars from virgin ore and from scrap indicates that 74 percent less energy and 41 percent less water are used in the recycling case. In addition,

## TABLE 3

ENVIRONMENTAL IMPACT COMPARISON FOR 1,000 TONS OF LOW GRADE PAPER*

| Environmental effect | Unbleached kraft pulp (virgin) | Repulped wastepaper 100% | Change from recycling (%)† |
|---|---|---|---|
| Virgin material use (oven-dry fiber) | 1,000 tons | 0 | −100 |
| Process water used | 24 million gal | 10 million gal | −61 |
| Energy consumption | $17 \times 10^9$ Btu | $5 \times 10^9$ Btu | −70 |
| Air pollution effluents (transportation, manufacturing, and harvesting)‡ | 42 tons | 11 tons | −73 |
| Waterborne waste discharged, BOD‡ | 15 tons | 9 tons | −44 |
| Waterborne wastes discharged, suspended solids‡ | 8 tons | 6 tons | −25 |
| Process solid waste generated | 68 tons | 42 tons | −39 |
| Net postconsumer waste generated | 850 tons§ | −250 tons¶ | −129 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

†Negative number represents a decrease in that category resulting from recycling.

‡(Biological oxygen demand.) Based primarily on surveys conducted in 1968-70.

§This assumes a 15 percent loss of fiber in papermaking and converting operations.

¶This assumes that 1,100 tons of wastepaper are needed to produce 1,000 tons of pulp. Therefore, 850 - 1,100 = −250 represents the net reduction of postconsumer waste.

air pollution effluents are reduced by 86 percent and mining wastes, by 97 percent (Table 5).

The results presented in Tables 2 through 5 were derived from surveys conducted from 1968 to 1970 and represent a situation of relatively uncontrolled pollution. As air and water pollution control legislation and implementing regulations become more effective, some of the costs of environmental degradation will be internalized by industry. This might result in improved environmental impacts of virgin material utilization and might decrease the cost advantage of virgin versus secondary materials. EPA is performing further analysis of this process, and the attendant costs and results will be presented in subsequent reports to Congress.

The results presented indicate that in most cases studied, the levels of atmospheric effluents, waterborne wastes, solid wastes, and energy and water consumption are substantially lower for resource recovery, as compared to virgin material

## TABLE 4

### ENVIRONMENTAL IMPACTS RESULTING FROM THE MANUFACTURE OF 1,000 TONS OF BLEACHED VIRGIN KRAFT PULP AND EQUIVALENT MANUFACTURE FROM DEINKED AND BLEACHED WASTEPAPER*

| Environmental effect | Virgin fiber pulp | Deinked pulp | Change from recycling (%)† |
|---|---|---|---|
| Virgin material use (oven-dry fiber) | 1,100 tons | 0 | −100 |
| Process water used | 47 million gal | 40 million gal | −15 |
| Energy consumption | $23 \times 10^{9}$ Btu | $9 \times 10^{9}$ Btu | −60 |
| Air pollution effluents (transportation, manufacturing, and harvesting)‡ | 49 tons | 20 tons | −60 |
| Waterborne waste discharged, BOD‡ | 23 tons | 20 tons | −13 |
| Waterborne wastes discharged, suspended solids | 24 tons | 77 tons | 222 |
| Process solid waste generated | 112 tons | 224 tons | 100 |
| Net postconsumer waste disposal | 850 tons§ | 550 tons¶ | −165 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

†Negative number represents a decrease in that category resulting from recycling.

‡Based on surveys conducted in 1968-70.

§This assumes a 15 percent loss of fiber in papermaking and converting operations.

¶This assumes that 1,400 tons of wastepaper are needed to produce 1,000 tons of pulp. Therefore, 850 − 1,400 = −550 represents the net reduction of postconsumer solid waste.

utilization. However, the full environmental impact of these results is difficult to assess completely. Residuals and wastes produce different degrees of environmental damage, depending both upon their composition and where they are released. Emissions in areas with high populations could affect public health and welfare, whereas in rural areas, plant and wildlife ecology could be altered. Further research and analysis are needed to evaluate the overall environmental impact of the different mixes and locations of emissions due to increased levels of recycling.

## ECONOMICS

There are a number of historical, technical, locational, attitudinal, and other reasons for the

TABLE 5

ENVIRONMENTAL IMPACT COMPARISON FOR 1,000 TONS OF STEEL PRODUCT*

| Environmental effect | Virgin material use | 100% waste use | Change from recycling (%)† |
|---|---|---|---|
| Virgin material use | 2,278 tons | 250 tons | −90 |
| Water use | 16.6 million gal | 9.9 million gal | −40 |
| Energy consumption | $23,347 \times 10^6$ Btu | $6,089 \times 10^6$ Btu | −74 |
| Air pollution Effluents | 121 tons | 17 tons | −86 |
| Water pollution | 67.5 tons | 16.5 tons | −76 |
| Consumer wastes generated | 967 tons | −60 tons | −105 |
| Mining wastes | 2,828 tons | 63 tons | −97 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

†Negative number represents a decrease in that category resulting from recycling.

decline of resource recovery. All of these can be translated into the factor of relatively high *total* costs for waste recovery, compared with virgin material processing. Secondary materials derived from municipal waste have a higher cost to the material user in almost every instance than do virgin materials.

Again glass, paper, and ferrous metals provide illustrations.

*Glass*

Cost comparisons of glass manufacture from either waste glass (cullet) or virgin raw materials depend primarily on the delivered cost to the plant of each raw material. Glass can be made from cullet in existing plants with only minor and inexpensive changes in process. Production costs are essentially the same with either raw material. Similarly, a new plant designed to use cullet would be very similar to a plant based on virgin materials and would be no more costly to construct.

Table 6 compares costs when virgin raw materials are used with the costs of using cullet. The lower end of the cullet price range reflects a transportation distance of 25 miles or less. As distance from the glass plant increases, the price obviously rises. Because most recovered glass would need to move more than 25 miles, the upper end of the range provides the best estimate.

Glass manufacturers are not likely to make even the minor process changes required to increase cullet consumption in cases where the cost of using virgin materials from well-established sources, with predictable supplies and prices, is equal to or less than that of bringing in an unfamiliar, possibly contaminated substitute.

*Paper*

The comparative economics of using supplemental wastepaper in existing mills for manufacturing certain paper products are shown in Table 7. These

## TABLE 6

### COST COMPARISON FOR GLASS*

| Cost component | Virgin materials ($/ton) | Cullet (waste glass) ($/ton) |
|---|---|---|
| Raw materials delivered | 15.48 | 0 |
| Cullet delivered | 0 | 17.77–22.77 |
| Fusion loss | 2.95 | 0 |
| Incremental handling costs at glass plant | 0 | 0.50–1.00 |
| Total | 18.43 | 18.27–23.77 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

## TABLE 7

### COMPARATIVE ECONOMICS OF PAPER MANUFACTURED FROM RECYCLED AND VIRGIN MATERIALS*

| Product | Linerboard | Corrugating medium | Printing writing paper | Newsprint |
|---|---|---|---|---|
| Baseline case (recycled fiber content) (%) | 0 | 15 | 0 | 0 |
| Baseline average operating cost ($/ton) | 78.50 | 79.50 | 80–120 | 125 |
| Supplemental fiber use (recycled fiber content) (%) | 25 | 40 | 100 | 100 |
| Operating cost with increased use of recycled fiber ($/ton) | 82.25 | 82.00 | 100-150 | 98 |
| Net cost of increased recycled fiber usage ($/ton) | 3.75 | 2.50 | 20-30 | 27 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

examples are by no means exhaustive of the many paper industry products, but these cases, which represent three products with different economic characteristics, support what would seem to be obvious from the industry's current orientation. The cost "penalty" for increasing the use of paper stock is $2.50 per ton for corrugating medium, $3.75 per ton for linerboard (corrugating medium and linerboard are the materials used to make corrugated boxes), and $20 to $30 per ton for printing writing paper. The latter cost differential results from the substantial upgrading of wastepaper that would be required to produce a product of the high quality presently required in the printing writing grade of paper. The cost of newsprint manufacture, however, is lowered by using 100 percent recycled fiber (deinked newsprint). This has been the only major new market for wastepaper in recent years.

The economics of constructing new mills based on either virgin or secondary fibers also show why the industry has preferred to build plants utilizing virgin fiber. An analysis of folding boxboard (combination board made from secondary fiber versus solid wood pulpboard made from virgin pulp) found that the return on investment for the virgin based plant was 8.1 percent whereas that for a plant based on wastepaper (combination board) was only 4.5 percent. Under such circumstances, construction of new combination board mills is highly unlikely.

*Ferrous Metals*

The costs to an integrated steel producer of using scrap versus ore are difficult to determine. The steel industry does not maintain, or at least does not report, such figures. Estimates have been made, however, which indicate that the cost of using high-grade scrap is higher than the cost of using ore.[7]

The point of equivalency of scrap and ore in the production process is the point where either hot molten pig iron or melted scrap is used to charge a basic oxygen furnace. The total cost of scrap at this point was estimated to be $44.00 per ton, including $33.50 purchase price of the scrap, $6.00 melting cost, $3.50 for scrap handling, and $1.00 for increased refractory wear caused by scrap usage. The cost of molten pig iron (which competes directly with scrap) was estimated at $37.50 per ton, including $28.50 for the ore and associated raw materials and $9.00 for melting cost. Thus, the cost of scrap ready for charging a basic oxygen furnace is about $6.50 per ton greater than that of the hot metal derived from ore at the same point. Thus, without a reduction in scrap cost of at least $6.00 to $7.00 per ton, it is unlikely that the utilization of scrap by existing steel mills in basic oxygen furnace steel production will substantially increase.

Nonintegrated steel mills using electric furnaces (which operate on a virtually 100-percent scrap charge), of course, find the use of scrap economical. These scattered mills are usually located near metropolitan areas, and transport cost of scrap is not a major expense.

The above cases illustrate the fundamental economic barriers to the increased utilization of secondary materials. The economics of recovery today result in the recovery of all waste materials that are of high quality and that can be obtained from reasonably concentrated sources. Extraction of materials from solid waste is limited both by the relatively low quality of such wastes, due to contamination and admixture with foreign materials, and by the relatively greater effort required to acquire such materials.

## ECONOMIC DISINCENTIVES

A part of the cost differential between secondary and virgin raw materials is, in fact, artificially created by public policy actions. Virgin materials enjoy depletion allowances and other subsidies such as favorable capital gains treatments. For example, because of the 15 percent depletion allowance on iron ore, the ore producer could lower his selling price by 13.5 percent without reducing his profit margin. Publicly controlled freight rates appear to discriminate against the movement of scrap materials. To a large extent, virgin material prices do not reflect the full costs of environmental degradation that the materials create. Furthermore, the fuels required for the energy to extract and process the virgin materials—which are high energy consumers—are also subsidized by depletion allowances.

Environmental regulations will tend to internalize pollution costs and may partially close the relative cost gap between use of virgin and recycled materials. However, the overall timing and impact of these measures is difficult to predict. Under the present market conditions, pollution regulations may in some cases work to the detriment of recycling. For example, in the paper industry, many combination board mills (the major users of secondary paper) are already economically marginal operations and will find it difficult to absorb additional pollution control expenditures. Also, many types of environmental degradation resulting from virgin material use (e.g., strip mining) are not currently subject to controls.

## RESOURCE RECOVERY TECHNOLOGY

Technology to process mixed municipal wastes for recovering materials, commodities, and energy has been, and is being, developed by private industry, generally without Federal support.

EPA's resource recovery demonstration program, carried out under Section 208 of the Solid Waste Disposal Act, is designed to demonstrate the major technologies that have been developed in areas where both economic and market conditions for successful demonstration can be found.

The major technical options being considered are the following: (1) material separation into salable components, (2) composting of waste and production of soil modifiers, (3) waste heat recovery in conventional incineration, (4) waste heat recovery in high-temperature incineration, (5) direct firing of prepared waste as fuel, (6) pyrolysis of waste to generate steam or gaseous, liquid, or solid fuel. Of these options, a number have already been or are now being demonstrated.

Wet material separation employing a system developed by the Black-Clawson Company has been demonstrated at Franklin, Ohio, with EPA support. Metals, glass, and salable pulp are separated after shredding.

A number of composting plants have been built and have been operated successfully from a technical point of view (See Appendix). The majority have failed, however, because markets for the compost products did not materialize. The rather high cost of producing compost is not sufficiently offset by income from its sale.

Waste heat recovery in conventional incineration has been demonstrated both here and abroad; this is also a well-known practice (See Appendix).

Direct firing of prepared waste as fuel is now being demonstrated in St. Louis, Missouri. Waste is shredded, ferrous metals are removed by a magnet, and the remaining waste, including nonferrous metals and broken glass, is introduced into a utility boiler where it is burned with coal to generate steam for the utility's turbines.

Partial separation of incinerator residues, i.e., the extraction of steel cans by magnets, has been demonstrated at a number of locations.

Major technical options or variants that have not yet been demonstrated include the following.

Total incinerator residue separation, as developed by the Bureau of Mines, recovers glass, nonferrous metals, and some fractions of the minerals in residues, in addition to iron and steel. A pilot plant has been operated by the Bureau of Mines.

Dry mechanical waste separation components, such as shredders, magnets, grinders, and conveyors, are commercially available. An air separator that performs a gross division of wastes into combustible and noncombustible fractions has been employed as part of an EPA contract with Combustion Power Equipment Company in Los Angeles, California. Material separators have been widely used in other industries such as mining and agriculture. To date, the application of these technologies to solid waste separation has not been fully exploited by industry because secure markets for output products do not exist.

Waste heat recovery techniques using high-temperature incinerators have been developed; all of these incinerators operate in a similar manner.

Pyrolysis systems have been developed by high-technology companies (Monsanto, Hercules, Garrett, Union Carbide). Like high-temperature incinerators, these are also very similar in operation. They can be designed to yield outputs of fuel gas, oil, and char, or they can be utilized directly to generate steam.

Economic data on the investment costs, operating costs, and revenues of major resource

recovery system options have been developed by Midwest Research Institute under contract with EPA and the Council on Environmental Quality. All of the major systems examined show a net cost of operation: revenues are not sufficient to cover all operating costs. In a municipally owned plant with an input capacity of 1,000 tons per day, net costs will range from a low of $2.70 per ton for fuel recovery by direct waste firing to a high of $8.97 per ton for incineration with electrical generation (Table 8). Whereas the costs indicate that resource recovery by processing is not a profitable venture, in those communities where disposal costs are high, the lower cost resource recovery options offer a means of reducing disposal costs.

Figure 1 shows that recovery system economics improve with size. These data are based on current prices for secondary materials (Table 9). The results show that recovery by processing could be attractive in large cities generating large quantities of waste if the increased quantities of recovered materials do not drive secondary material prices down. Table 10 shows the sensitivity of system economics to the market price of recovered materials. It can be seen that if higher prices are obtained, which may be the case if incentives for use of secondary materials are instituted, system economics are significantly improved. Using the case of material recovery as an example, a 50-percent increase in prices results in a reduction of net costs from $4.77 per ton to $2.56 per ton. A

TABLE 8

SUMMARY OF RECYCLING SYSTEM ECONOMICS*†

| System concept | Primary type of recovery | Capital investment (thousands of dollars) | Total annual cost (thousands of dollars) | Resource value (thousands of dollars) | Net annual cost (thousands of dollars) | Net cost per input ton ($) |
|---|---|---|---|---|---|---|
| Material recovery | Material | 11,568 | 2,759 | 1,328 | 1,431 | 4.77 |
| Residue recovery after incineration | Material | 10,676 | 2,689 | 535 | 2,154 | 7.18 |
| Incineration and steam recovery | Energy | 11,607 | 3,116 | 1,000 | 2,116 | 7.05 |
| Incineration and electrical generation | Energy | 17,717 | 3,892 | 1,200 | 2,692 | 8.97 |
| Pyrolysis | Energy | 12,334 | 3,287 | 1,661 | 1,626 | 5.42 |
| Composting (material energy) | Energy | 17,100 | 2,987 | 1,103 | 1,884 | 6.28 |
| Fuel use (supplementary) | Energy | 7,577 | 1,731 | 920 | 881 | 2.70 |
| Incineration | Disposal | 9,299 | 2,303 | 0 | 2,303 | 7.68 |

*Source: Midwest Research Institute. Resource recovery from mixed municipal solid wastes. Unpublished data, 1972.

†Based on municipally owned, 1,000 ton per day plant with a 20-year economic life, operating 300 days per year, and interest at 5 percent.

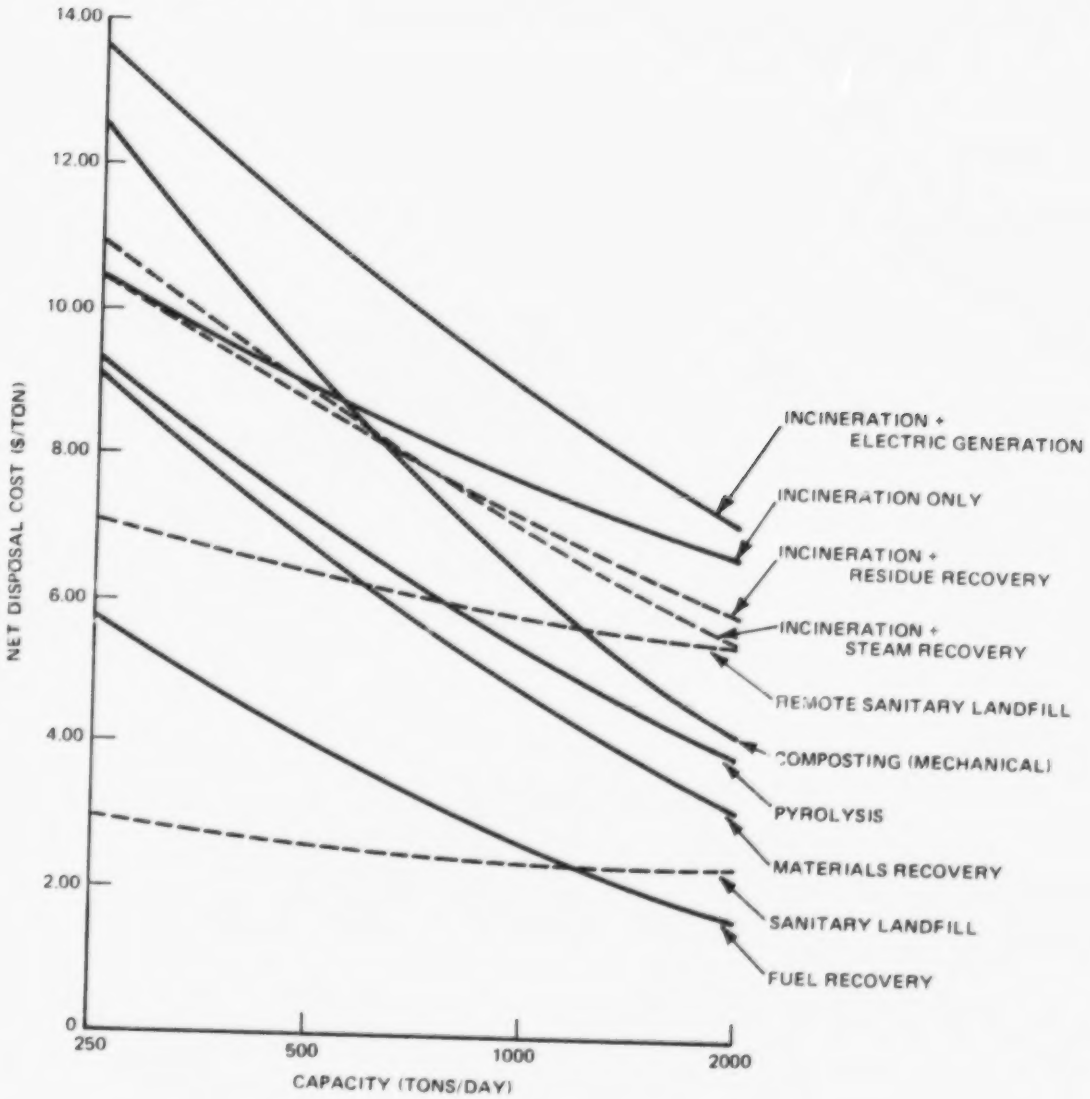


Figure 1. Net disposal costs associated with municipally owned resource recovery systems at various plant capacities (20-year economic life; 300 days per year operation).*

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

TABLE 9

QUANTITY AND VALUE OF RECOVERABLE RESOURCES IN MIXED WASTE*+

| Resource | Yield ‡ (%) | Recovered quantity available § | Estimated unit Value FOB plant ($/unit) | Total annual revenues ($) |
|---|---|---|---|---|
| Paper | 45 | 45,000 tons | 15.00 | 675,000 |
| Glass | 70 | 16,800 tons | 10.00 | 168,000 |
| Ferrous metals ¶ | 90 | 20,400 tons | 12.00 | 244,000 |
| Nonferrous metals | 67 | 1,200 tons | 200.00 | 240,000 |
| Oil | 100 | 1,440,000 MBtu | .70 | 1,008,000 |
| Fuel (as a coal substitute) | 100 | 2,700,000 MBtu | .25 | 675,000 |
| Steam | 100 | 2,000,000 M lb | .50 | 1,000,000 |
| Electric energy | 100 | 200,000,000 kW-hr | .006 | 1,200,000 |
| Humus | | 75,000 tons | 6.00 | 450,000 |

*Source: Midwest Research Institute. Resource recovery from mixed municipal solid wastes. Unpublished data, 1972.

+Not all of these values are additive. For example, if paper is reclaimed as fiber, it cannot also be recovered as oil or fuel.

‡Yield equals the percent of the material or energy in the waste that can actually be recovered. In general, losses and technical limitations make this less than 100 percent.

§Assumes a 1,000-ton/day plant operating 300 days/year or 300,000 tons of waste. Also assumes recovery rates based on technology assessment of available systems.

¶This assumes recovery from mixed waste. If recovery is from incinerator residue, the value is assumed to drop to $10/ton, and only 12,700 tons are recoverable.

material price decrease of the same amount would raise net costs to $6.98.

The costs presented in Tables 8 and 10 suggest that source recovery is a more economical option than incineration. The fact that there is no apparent move to install resource recovery systems is partially explained by the fact that the markets for recovered commodities are uncertain. Cities are unable to obtain purchase contracts with local buyers of waste materials at fixed prices. The failure rate of compost plants, due to lack of markets, has solidified feelings of market uncertainty. Finally, traditional municipal reluctance to undertake large-scale capital investment–particularly where there is an element of risk–and other institutional problems have also contributed to the failure to move to resource recovery systems.

In summary, technology is, in most cases, available for implementing resource recovery through the processing of mixed municipal wastes. The technical processing route is costly, but in some of the technical options, costs approximate those of other means of disposal. Although technological improvements would result in some cost reductions, techno-

TABLE 10

SENSITIVITY OF SYSTEM ECONOMICS TO MARKET VALUE OF RECOVERED RESOURCES*

| System concept | Net cost based on resource selling prices as a percent of base value ($/ton) | | | |
|---|---|---|---|---|
| | 150 percent | 100 percent | 50 percent | No resource value recovered |
| Material recovery | 2.56 | 4.77 | 6.98 | 9.20 |
| Incineration and residue recovery | 6.29 | 7.18 | 8.08 | 8.96 |
| Incineration and steam recovery | 5.39 | 7.05 | 8.72 | 10.38 |
| Incineration and electrical generation | 6.98 | 8.97 | 10.98 | 12.98 |
| Pyrolysis | 2.65 | 5.42 | 8.18 | 10.96 |
| Composting | 4.44 | 6.28 | 8.12 | 9.95 |
| Fuel recovery | 1.17 | 2.70 | 4.24 | 5.77 |

*Source: Midwest Research Institute, Resource recovery from mixed municipal solid wastes. Unpublished data, 1972.

logy is not likely to improve dramatically the marketability of products. If incentives for secondary material consumption were instituted and if improved prices for waste-based commodities were established, further technology development by the private sector could be expected.

## RECOVERY FROM MIXED MUNICIPAL WASTE

To recover materials from mixed municipal waste, economics must be favorable at two key points. The municipality must find the cost of resource recovery competitive with disposal. Second, the user of the materials from these systems must find the cost of these secondary materials competitive with virgin material substitutes. Recovery of materials from mixed municipal waste requires processing. With the exception of some 20 very large cities, disposal costs of most communities are lower ($2 and $3 per ton) than the resource recovery alternative. As shown, recovery processing costs tend to exceed revenues from the sale of products, and the resulting net cost is higher in most places than current disposal costs.

Even in areas where disposal costs are already high—in excess of $5 per ton—resource recovery is limited because no markets can be guaranteed for recovery plant outputs at the tonnage levels at which they can be produced.

From the standpoint of the municipality, then, two changes that would bring about larger scale recovery of mixed municipal waste are higher prices for recovery plant outputs or, alternatively, reduced recovery plant production costs and, second, an increase in demand for waste-based raw materials.

These requirements, however, are somewhat at odds with the requirements of the user who must purchase the outputs of such plants. As has been shown, the economics of virgin material use are already more favorable than the economics of secondary material use. Lower waste prices are needed to change this situation. To insure a demand for secondary materials, either they must decrease in price or their use must be subsidized.

# 3. MAJOR OPTIONS

EPA's studies have progressed to the point that the major available options for bringing about an increased rate of resource recovery–where such action can be justified on environmental and conservation grounds–are generally identifiable. The fundamental requirement is to create a situation in which users of industrial materials substitute secondary materials for virgin materials to the extent that this results in more efficient use of resources. This situation could be brought about by three types of activities: (1) actions to inhibit the use of virgin materials; (2) actions to create a demand for secondary materials; (3) actions to create a supply of secondary materials of such quality and at such a price that they would appropriately satisfy the new demand.

Inhibitory mechanisms, aimed at restricting the consumption of virgin materials, would normally take the form of disincentives or regulatory actions. Actions to create demand or supply would normally require the provision of positive incentives. An analysis of each of the major options follows.

## INHIBITION OF VIRGIN MATERIAL USE

If the supplies of virgin materials available to industry were denied or restricted, the cost of the remaining available portion would rise as a consequence of continuing demand. In relation to secondary materials, then, virgin materials would become more expensive, and more secondary materials would be used. Similarly, if the costs of virgin materials were artifically raised (by taxation, removal of depletion allowances, capital gains treatment, or other means), the same consequence would result.

The desirability of major intervention into virgin material use to increase recycling is questionable on the grounds that a very large material tonnage (5.8 billion tons) may have to be affected to increase a small portion (55 to 60 million tons).

Several "natural" events are likely to cause the cost of virgin materials to rise without any form of government intervention. These events include (1) tighter pollution control regulations and enforcement, resulting in higher pollution-control costs; (2) increasing energy costs, which will proportionately affect virgin materials more because they are more energy intensive than secondary materials; (3) depletion of high-quality domestic reserves and the need to exploit lean ore deposits of high-quality or to import raw materials across greater distances; (4) potentially adverse foreign trade policies. The timing and impact of these market correctives are difficult to predict but are expected to be significant.

"Artificial" intervention is possible through instituting taxes on virgin materials and/or removing or modifying the favorable tax treatment of virgin materials and energy substances, regulating virgin materials available from Federal land, denying markets to virgin materials through Federal procurement policies, changing transportation costs through Federal regulation of rail and ocean freight rates, changing federally mandated labeling regulations, and, at the extreme, instituting national materials standards that would limit the use of major virgin materials to some percentile below that now common.

The costs, benefits, and probable effectiveness of each major action listed above are being analyzed. Based on initial findings, EPA sees justification for more aggressive Federal procurement policies to limit the use of virgin materials in products (with all the implied consequences of such a leadership posture), actions to remove freight rate disparities that appear to favor virgin materials, and removal of labeling regulations that discourage consumer purchasing of products that contain "waste" materials.

An example of Federal procurement changes already exists. The changes introduced in 76 paper product specifications by the General Services Administration, under orders from the President, are already having some impact on paper and board production. Intensification of such actions is certain to have beneficial impacts on resource recovery.

Fiscal measures (e.g., taxes to discourage virgin use) could be addressed to the artificial economic benefits that now favor virgin material use. Such measures, however, would have a variety of other impacts as well, which are being evaluated to determine whether fiscal measures to inhibit the use of virgin materials are cost effective. In light of a series of natural events–especially rising energy costs–that will increase virgin material costs, fiscal intervention may appear neither necessary nor desirable.

Regulatory actions are viable alternatives for increasing resource recovery but relative to virgin material resource use, such actions need further evaluation to determine their side effects, which may be adverse.

## DEMAND CREATION

EPA's investigations to date lead to the conclusion that positive economic incentives may be desirable to arrest the relative decline of material recovery and to increase the proportion of total national material needs satisfied by waste-based raw materials.

There is evidence that energy recovery from mixed municipal waste will become a very real option to both private and public sector waste management organizations without incentives of any sort and that limited materials recovery steel, aluminum, and glass will accompany such energy recovery activities.

The most efficient incentive for material recovery would be one that results in new industrial demands for secondary materials, such as some form of tax incentive or subsidy payment to users of secondary materials. If an incentive results in a "demand pull" by industry, such demand will automatically result in changes in the way wastes are stored, collected, and processed. The key to increased recovery is the waste commodity buyer rather than the commodity supplier. Only if the buyer finds waste materials a more economical alternative than virgin materials will greater quantities be utilized. Incentives provided directly to the buyer are most likely to have the most dramatic effect on his actions.

Demand-creation incentives can take a variety of forms. The particular form that the incentive takes is important from the administrative and legal points of view. Also, different types of incentives have different efficiencies (cost–effectiveness). Regardless of mechanism used, the important point is that the material producer (steel mill, papermill, glass plant, etc.) should find himself in a situation where the use of secondary material is to his economic advantage.

Potentially, several types of incentive measures satisfy this criterion: investment tax credits for using secondary materials, subsidy payments or bounties, subsidy of plant and equipment for processing or using secondary materials, etc. If the incentive is made available directly to the material consumer, a demand for waste materials will result.

Functionally, the incentive must be high enough so that at the point of material consumption, the cost of the secondary material to the buyer is at least the same, i.e., in the same quality range, as the cost of the virgin material. Investigations are underway to identify the level of necessary incentives. As shown in a previous section, it appears that the incentive required to "equalize" the costs of virgin and secondary materials would range from $2.50 to $30.00 per ton of material recovered. These values are based on a limited number of comparisons and should be viewed as somewhat tentative. It is estimated that an across-the-board incentive sufficient for a substantial increases in resource recovery would range from $3 to $5 per ton of material recovered. A subsidy of this magnitude should be largely offset by savings in disposal cost because recycled materials would be removed from the waste stream and, thus, would not incur the cost of landfill or incineration. In addition, there would be important environmental benefits from increased recycling.

## SUPPLY CREATION

Incentives for demand creation are viewed as sufficient inducements to raise about resource recovery at an accelerated rate. Such incentives, if

appropriately designed, should spur private and public investment in resource recovery plants and systems that would deliver to industry the types and quantities of secondary materials it might demand.

As incentives bring about consumer demand for increased quantities of secondary materials, the demand will reverberate down the chain of suppliers and will bring about some changes in supply patterns. It is likely, for example, that increased "skimming," or removal from wastes before discard, of accessible wastes, such as newspapers, corrugated boxes, and office papers, would occur at municipal and commercial sources and that such recovery would take place at lower overall costs than technological sorting.

Most of the solid waste materials that would be demanded by industry now pass through the hands of municipal solid waste management organizations that collect waste in mixed forms. To sell all proportions of waste now collected, these organizations face two alternatives: to collect waste fractions separately or to process mixed wastes into separate fractions.

Both alternatives have drawbacks. Separate collection of different waste fractions, while once widely practiced, has virtually disappeared. Combined waste collection, using the more efficient compactor truck, has become standard in residential, institutional, and commercial waste collection practice. Reinstituting separate collection would require changes in practices and equipment.

The processing option is capital intensive. The economics of processing require large plant sizes to take advantage of economics of scale. For the economics to be attractive, plant sizes of 1,000 tons per day of input or higher are required. There are few communities with such high generation rates.

If demand incentives result in higher secondary material prices, public and private waste management organizations would be able to justify the processing of municipal wastes for recovery in lieu of processing for disposal. Higher prices for waste-based commodities will also permit the use of smaller capacity plants; the higher prices will compensate for the higher processing costs of small plants.

In smaller communities, where recovery by processing is not likely to be economical, providing supplies via separate collections is a possibility. The separate collection option, which was once practiced extensively, will require technical, institutional, and social changes to become a part of today's society. At this point, enough knowledge has been gained to see that citizen enthusiasm for resource recovery, as expressed in the thousands of neighborhood recycling centers, holds the potential for new and innovative options for solid waste collection. Furthermore, the successful experience of Madison, Wisconsin—where city crews collect newspapers separated from other wastes by the citizenry—indicates that alternatives to large-scale recovery plants do indeed exist.

Such approaches to supply creation are still being analyzed as part of EPA's resource recovery studies program.

## OTHER OPTIONS

In addition to action programs that would have a direct impact on resource recovery, a number of related activities are also under consideration whose consequences would be to attack the broader problem of "excessive material consumption" in the United States, rather than one aspect of that problem, low resource recovery rates.

Source reduction proposals are usually aimed at a particular product, such as beverage containers, or a class of products like packaging or appliances.

Source reduction options fall into four categories: (1) bans or other disincentives applied to a product or class of products; (2) setting of performance standards that will result in longer lived products, whereby more "use" or "service" is obtained from a given quantity of materials than is the case if rapid obsolescence is promoted; (3) substitution of production processes with low waste yields for waste-intensive processes, for instance, dry papermaking in place of wet pulping; (4) substitution of products with low material requirements for those with high material requirements, for instance, electronic calculators for the more material-intensive mechanical calculators or substitution of electronic communications media for media that require paper.

EPA's investigation of source reduction concepts is currently aimed at packaging and other disposables, products that are particularly significant in their contribution to solid waste quantities and

whose consumption has been growing rapidly. An EPA study is underway to examine alternate taxing and regulatory measures for reducing the quantities of packaging materials consumed.

Such measures might be successful in either reducing consumption of packaging and other disposables; stimulating designs of more recyclable packaging or products; or providing funds for defraying the litter cleanup, collection, and disposal costs presently associated with these materials. The secondary effects of these measures, such as economic dislocations and employment disruptions, are also being examined.

Of the various major options available for increasing the rate of recovery, intensified Federal procurement of waste-based products and further exploration of positive demand incentives appear most desirable in the long term, accompanied by activities to bring into line freight rates of virgin and secondary materials. More information is needed about the necessity for and the effects, fairness, and workability of both source reduction and resource recovery incentive concepts before such measures are implemented.

Demand creation would be achieved most efficiently by the direct route of rewarding the waste consumer for using secondary materials. Incentives for demand creation, if properly designed, may bring about resource recovery at an accelerated rate and would probably spur private and public investment in resource recovery plants and systems to supply secondary materials. Certain changes in supply patterns may emerge that will result in the circumvention of the recovery plants by some waste materials. "Skimming" of accessible wastes like newspapers, corrugated boxes, and office papers is such a change. For smaller communities where recovery by processing is not likely to be economical, provision of supplies via separate collection is a potential solution.

Actions aimed at removing certain artificial barriers are under serious consideration by EPA, especially Federal procurement policies to increase the use of secondary materials in products and actions to remove freight rate disparities that appear to favor virgin materials.

Taxes and regulations to reduce the consumption of certain product categories, such as packaging, and thereby reduce the load on the solid waste stream are presently under investigation. Stimulation of more recyclable package designs and provision of funds for litter cleanup are secondary benefits of such actions.

# 4. PROGRAM ACTIVITIES

The foregoing presentation and preliminary conclusion, as well as the data, information, and discussions of specific materials included in the Appendix, are based on EPA resource recovery program activities, carried out both by in-house staff efforts and contract research in support of the internal analysis.

An overview of the basic plan for carrying out the congressional mandate is shown in Figure 2. The problem is defined in terms of the adverse environmental effects of material processing and disposal and efficiency of resource utilization. The broad solutions identified for the problem are increased resource recovery and source reduction activities. A number of policy options available to achieve the solution are shown. Next, specific program activities to implement the policy option are shown arranged into "primary" and "secondary" priority categories. Finally, an evaluation procedure, by which specific action programs will be selected for recommendation, is outlined.

Figure 3 shows the various alternatives available for reaching the objective of increased waste utilization; Figure 4 illustrates the alternatives available to obtain the objective of source reduction; Figure 5 illustrates the points in the material cycle where the various action program alternatives would have their impacts.

For purposes of discussion, EPA's program efforts can be classified into three types of activities: (1) background studies that provide for understanding the subject of resource recovery in its many facets; (2) studies to formulate and analyze action programs; (3) studies to evaluate the impacts and effectiveness of action programs that appear to have merit. In what follows, the various past, ongoing, and projected activities of EPA will be discussed under these headings.

## BACKGROUND STUDIES

Background investigations include data collection, survey, and information classification to establish the status and trends of recycling and to identify problems, barriers, and opportunities for increased waste use. A number of background investigations have been completed to date and are nearing publication. The following is a list of completed studies:

(1) *An analysis of Federal programs affecting solid waste management and recycling*, SCS Engineers, 1971.

(2) *Catalog of resource recovery systems for mixed municipal waste*, Midwest Research Institute and Council on Environmental Quality, 1971.

(3) *Identification of opportunities for increased recycling of ferrous solid waste*, Battelle Memorial Institute and Institute of Secondary Iron and Steel, 1971.

(4) *Recovery and utilization of municipal solid wastes*, Battelle Memorial Institute, 1971.

(5) *Salvage markets for commodities entering the solid waste stream an economic study*, Midwest Research Institute, 1971.

(6) *Studies to identify opportunities for increased solid waste utilization* (Studies completed for aluminum, lead, copper, zinc, nickel, stainless steel, precious metals, paper, and textiles). Battelle Memorial Institute and National Association of Secondary Materials Industries, 1971

Review of this information is underway, data and information gaps have been identified, and the need for further background investigations has been established.

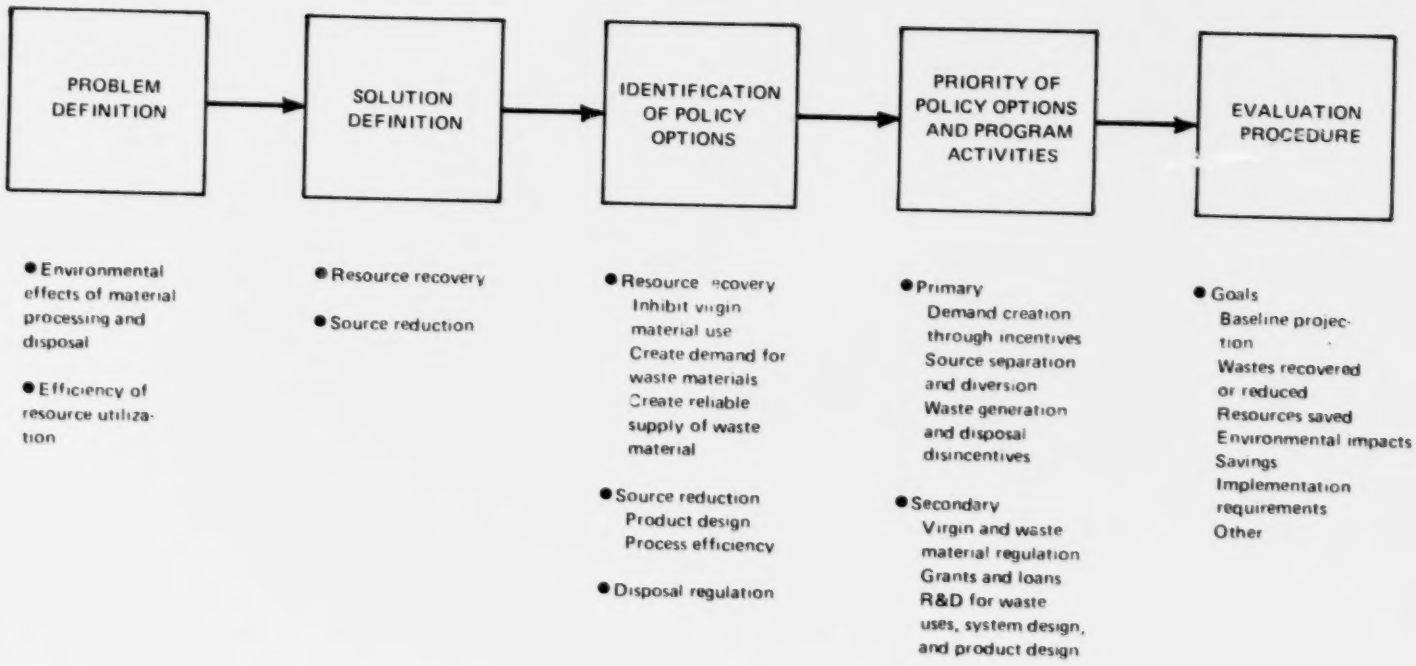


Figure 2. Overview of a plan for resource recovery and source reduction.

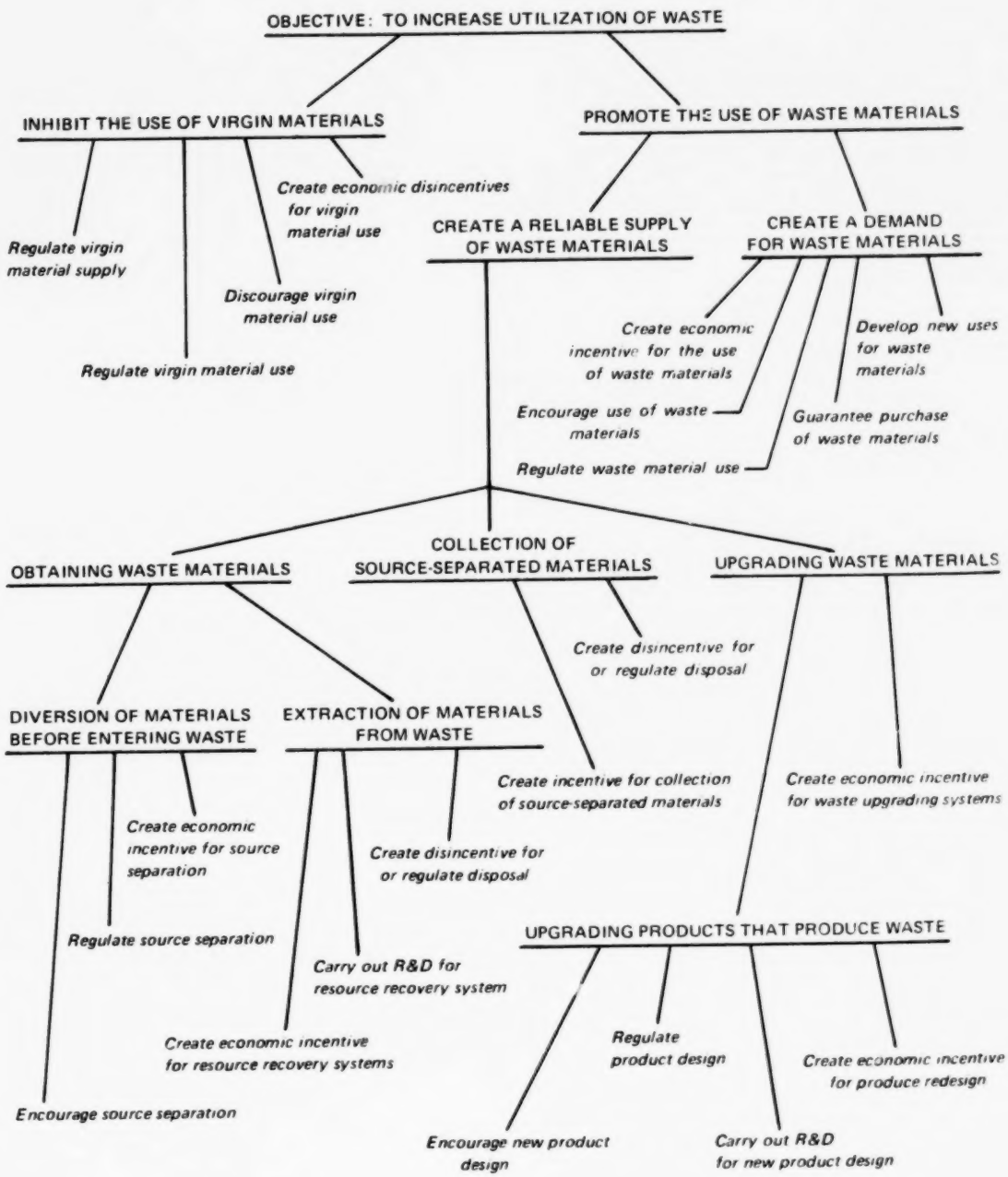
OBJECTIVE: TO INCREASE UTILIZATION OF WASTE
INHIBIT THE USE OF VIRGIN MATERIALS
PROMOTE THE USE OF WASTE MATERIALS
Create economic disincentives for virgin material use
Regulate virgin material supply
Discourage virgin material use
Regulate virgin material use
CREATE A RELIABLE SUPPLY OF WASTE MATERIALS
CREATE A DEMAND FOR WASTE MATERIALS
Create economic incentive for the use of waste materials
Develop new uses for waste materials
Encourage use of waste materials
Guarantee purchase of waste materials
Regulate waste material use
OBTAINING WASTE MATERIALS
COLLECTION OF SOURCE-SEPARATED MATERIALS
UPGRADING WASTE MATERIALS
Create disincentive for or regulate disposal
DIVERSION OF MATERIALS BEFORE ENTERING WASTE
EXTRACTION OF MATERIALS FROM WASTE
Create incentive for collection of source-separated materials
Create economic incentive for waste upgrading systems
Create economic incentive for source separation
Create disincentive for or regulate disposal
Regulate source separation
UPGRADING PRODUCTS THAT PRODUCE WASTE
Carry out R&D for resource recovery system
Create economic incentive for resource recovery systems
Regulate product design
Create economic incentive for produce redesign
Encourage source separation
Encourage new product design
Carry out R&D for new product design

Figure 3. Resource recovery policy options.

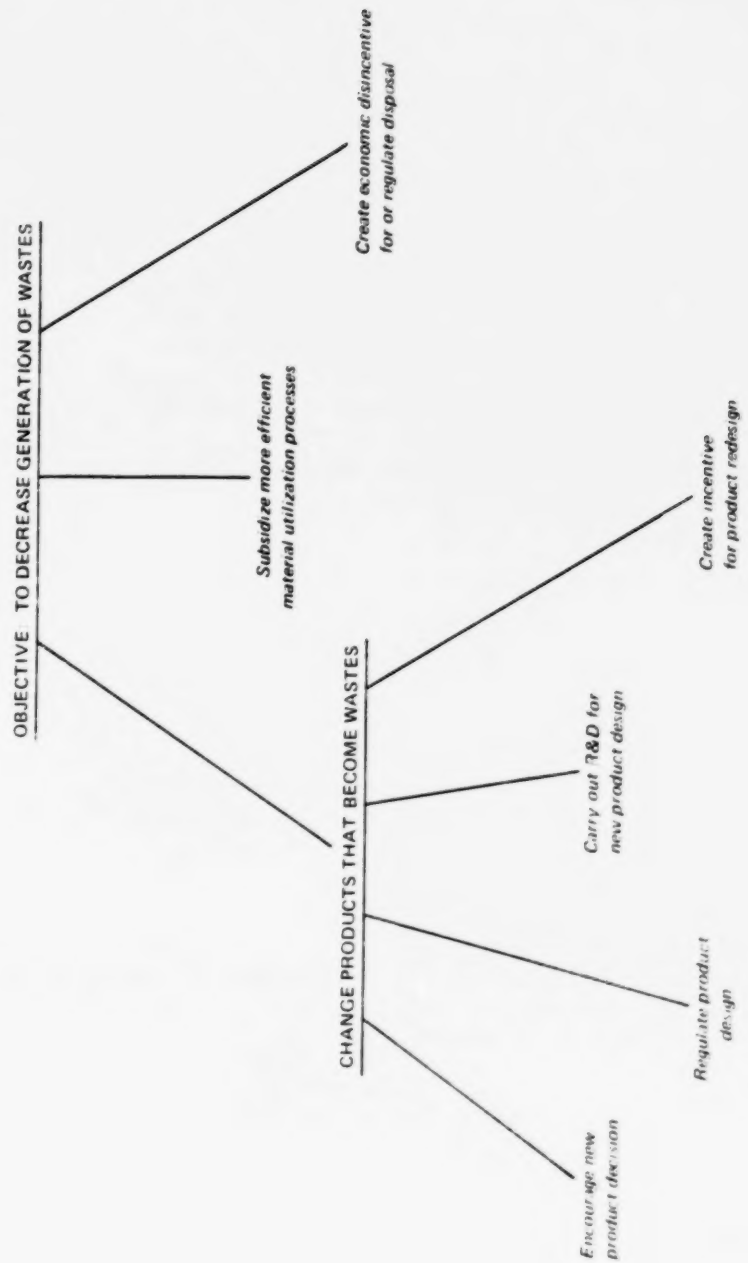
OBJECTIVE: TO DECREASE GENERATION OF WASTES
Create economic disincentive for or regulate disposal
Subsidize more efficient material utilization processes
CHANGE PRODUCTS THAT BECOME WASTES
Create incentive for product redesign
Carry out R&D for new product design
Regulate product design
Encourage new product decision

Figure 4. Source reduction policy option

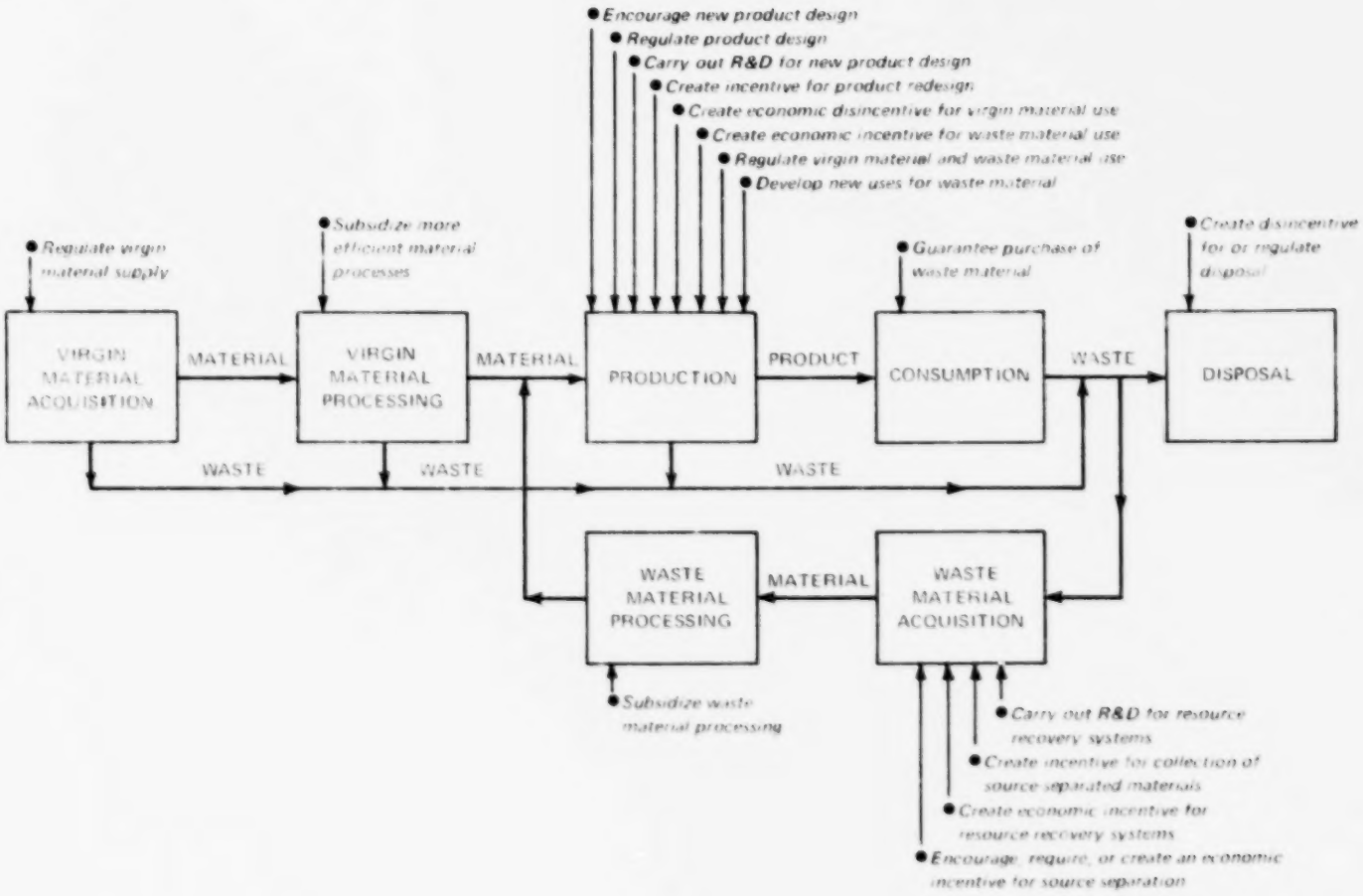


Figure 5. Application of resource recovery and source reduction policy options.

*Baseline*

To assess an incentive mechanism designed to increase waste recovery, it is first necessary to project the amount of future recycling likely to occur in the absence of the proposed incentive. Factors that could influence this baseline are (1) rising municipal disposal costs; (2) environmental legislation; (3) recovery technology development; (4) rising energy prices; (5) change in labor productivity; (6) private sector and local government actions. An investigation is being performed to forecast this baseline in the absence of Federal activity.

*Recycling Possibilities*

It is also important to estimate the practical upper limits on recovery, to assess the effectiveness of proposed recycling measures. It is not feasible to recover all solid waste generated. The amount available for recycling is determined by factors such as (1) losses in processing, collection, and handling; (2) amounts generated in remote areas; (3) self-disposal activities; (4) materials dispersed in trace quantities; (5) materials concealed or mixed in products. The practical limits on recycling are being projected to serve as a guide for evaluating recycling activities.

*Freight Rates*

Transport rates may have an unfavorable effect on the prices of secondary materials as compared to virgin materials. However, differences that exist may be justified by cost to the carrier. An investigation of the basis and structure of transport rates is being performed in an attempt to (1) compare actual freight rates for secondary and primary materials; (2) compare carrier costs of shipping and factors affecting this cost; (3) establish the effect of rates on the relative prices of virgin and waste materials.

*Source Separation and Collection*

To analyze incentives and policies that promote increased recycling, the reliability and costs of obtaining wastes from different sources must be known. There are three source separation techniques currently employed to collect wastes segregated at households or business establishments: (1) community recycling centers, (2) separate collections (by volunteer organizations, municipal or private collectors, and secondary material dealers), (3) separation of wastes during regular household collections. An example of the latter type of operation exists in Madison, Wisconsin, where segregated newspapers are collected with other household wastes and placed in a separate bin hung below the collection vehicle.

To provide the background information needed to evaluate these techniques, studies will be carried out to assess (1) consumer attitudes to source separation techniques; (2) costs involved in collecting segregated materials and transporting them to users; (3) amounts of material that can feasibly be recycled through these channels.

## FORMULATION OF ACTION PROGRAMS

Work in this area involves identifying and formulating means of increasing recycling through demand creation, supply creation, and inhibiting virgin material use. The following list contains studies of incentive alternatives that have been completed but are not released:

(1) *An Analysis of the Abandoned Automobile Problem*, Booz-Allen Hamilton, 1972.

(2) *An Analysis of the Beverage Container Problem with Recommendations for Government Policy*, Research Triangle Institute, 1972.

(3) *The Economics of the Plastics Industry*, Arthur D. Little, 1972.

(4) *Strategies to Increase Recovery of Resources from Combustible Solid Waste*, International Research and Technology, 1972.

(5) *Incentives for Tire Recycling and Reuse*, International Research and Technology.

The studies are presently under internal review, and where appropriate, recommendations will be forthcoming. The contract reports will be available for public distribution when the review is complete.

Program plans being developed for incentive and regulatory measures will be analyzed and evaluated in the next year. Economic incentives include (1)

recycling tax credit or subsidy for the use of post-consumer waste; (2) investment credit or subsidy for recovery equipment; (3) virgin material tax to increase cost of virgin material use; (4) waste generation tax to reduce the amount of waste produced; (5) government procurement to create a demand for waste materials; (6) depletion allowance adjustment to increase costs of virgin materials. Regulatory measures include (1) transport rate adjustment to equalize freight rates; (2) material standards specifying waste use in certain products; (3) virgin resource control on Federal lands; (4) regulation of waste and virgin material imports and exports.

## EVALUATION

Evaluation of the programs for economic incentives and regulatory measures consists of determining (1) wastes recycled; (2) resources conserved; (3) environmental impacts; (4) costs and savings; (5) implementation requirements; (6) other impacts such as employment, foreign trade, and industrial dislocation.

Work in this area involves, first, developing a methodology for performing the evaluation of the different aspects and, second, applying the methodology to the specific incentive and regulatory measures. Environmental impact analysis for paper, ferrous metals, and glass has been started (*Economic and Environmental Analysis*, studies completed for paper, ferrous metals, and glass, Midwest Research Institute and Council on Environmental Quality, 1971) and a preliminary cost-effectiveness study has been performed for one type of incentive, the recycling tax credit (*Preliminary Report on a Federal Tax Credit Incentive for Recycling Post Consumer Waste Materials*, Resource Planning Associates, 1972).

As will be discussed, additional work is required in the areas of predicting waste recycling and of estimating resource requirements and environmental impacts. The costs and savings follow directly from these measures. The implementation requirements and other impacts must be evaluated on an individual basis for each particular incentive or regulatory mechanism.

### *Predicted Recycling*

To predict the amount of waste material that would be recycled as a result of an incentive or regulation, it is necessary to estimate the elasticity of supply and demand as they affect prices for wastes and competitive virgin materials. This requires an analysis of historical price-quantity data; financial analyses to determine the effect on profit, return, and investment decisions; and an analysis of material processing costs. Work aimed at recycling through the major waste-using industries, such as wastepaper, scrap steel, and glass, is underway.

### *Environmental Impacts and Resource Consumption*

Work in this area involves laying out the entire waste material use system from acquisition to disposal. At each stage of the system, the air and water pollution produced are calculated along with the energy, water, and materials consumed. Comparisons are made with and without recycling, and the net environmental impact is determined. The work completed for paper, ferrous metals, and glass will be expanded to include calculation of the cost savings of pollution abatement due to recycling. Similar analyses will be carried out for aluminum, rubber, textiles, and plastics.

In summary, evaluating regulatory mechanisms and incentives involves (1) determining the effectiveness of the proposed measures, (2) comparing this to the recycling baseline and practical upper limit; (3) estimating costs and benefits; (4) making an informed judgment as to the value of the measure.

The program activities described are aimed at providing the information necessary to formulate meaningful resource recovery policy. In the last half of the fiscal year ending June 30, 1973, recommendations will be made for measures to accomplish the goal of increased resource recovery on an environmentally, economically, and socially sound basis. These measures will be described in the Second Annual Report to Congress.

# APPENDIX

## Recycling of Specific Wastes

### PAPER

*Status and Trends*

Paper is one of the major manufactured materials consumed in the United States and the largest single component—35 to 45 percent by weight—of collected municipal waste. In 1969, the Nation consumed 58.5 million tons of paper, and by 1980, this is projected to increase to about 85.0 million tons (Figure A-1). Paper, paperboard, and construction paper and board are the three major paper categories and accounted for 51.5, 40.8, and 7.7 percent, respectively, of the 1969 paper consumption.

Only 17.8 percent (10.4 million tons) of the paper consumed in 1969 was recovered for recycling, compared with 23.1 percent in 1960 and 27.4 percent in 1950.[14] Most of the remainder was discarded as waste (put in landfills or dumps, incinerated or littered), and a portion was diverted, obscured, or retained in other products. Trends in disposal and recycling (Figure A-1) show that the proportion of paper recycled after consumption has been steadily decreasing. This downward trend in recovery ratio, coupled with an increase in consumption, has resulted in an accelerated rate of wastepaper disposal. Between 1956 and 1967, wastepaper disposal increased nearly 60 percent, from 22 million tons per year to 35 million tons per year.[15]

*Sources of Waste*

Wastepaper can be classified into four major grades: mixed, news, corrugated, and high grades, accounting for 27.4, 19.8, 32.6, and 20.2 percent, respectively, of the wastepaper recovered in 1967. This wastepaper comes from residential, commercial, and conversion sources, which account for 16.6, 43.6, and 39.8 percent, respectively, of the 1967 paper recovery. Table A-1 shows the relationships between the waste grades and sources. The recovery pattern of paper wastes follows directly from the characteristics of each wastepaper source.

Wastepaper generated in conversion operations, where paper and board are made into consumer products, is almost totally recovered. It is easily accessible and generally uncontaminated, and almost half of such waste consists of desirable high grades. This waste is often baled onsite by the converter and never enters the waste stream.

At the opposite extreme, paper waste from residential sources is widely dispersed and highly contaminated with adhesives, coatings, and other materials in the waste stream that are costly and difficult for papermills to remove. Thus, almost none of the mixed paper in residential waste is recovered.

The only paper recovered in significant quantities from residential waste is old news. Recovered newspapers are separated from other waste by homeowners and are usually collected by charitable organizations. Some municipalities have begun experimenting with collecting newspapers along with the regular refuse collection by placing them in special racks on the collection vehicles. This offers promise for increasing the recovery of old newspapers for residences.

Commercial waste consists largely of business papers, mail, and packaging materials, especially corrugated boxes, and is usually concentrated at commercial/retail centers. It is obviously more accessible and desirable than mixed papers from residential sources but generally less so than conversion wastes. Corrugated boxes comprise about 52 percent of the commercial wastepaper recovered. They are usually baled or at least kept separate from other waste by the store or office. Significant quantities of mixed papers are also recovered, because they often occur at

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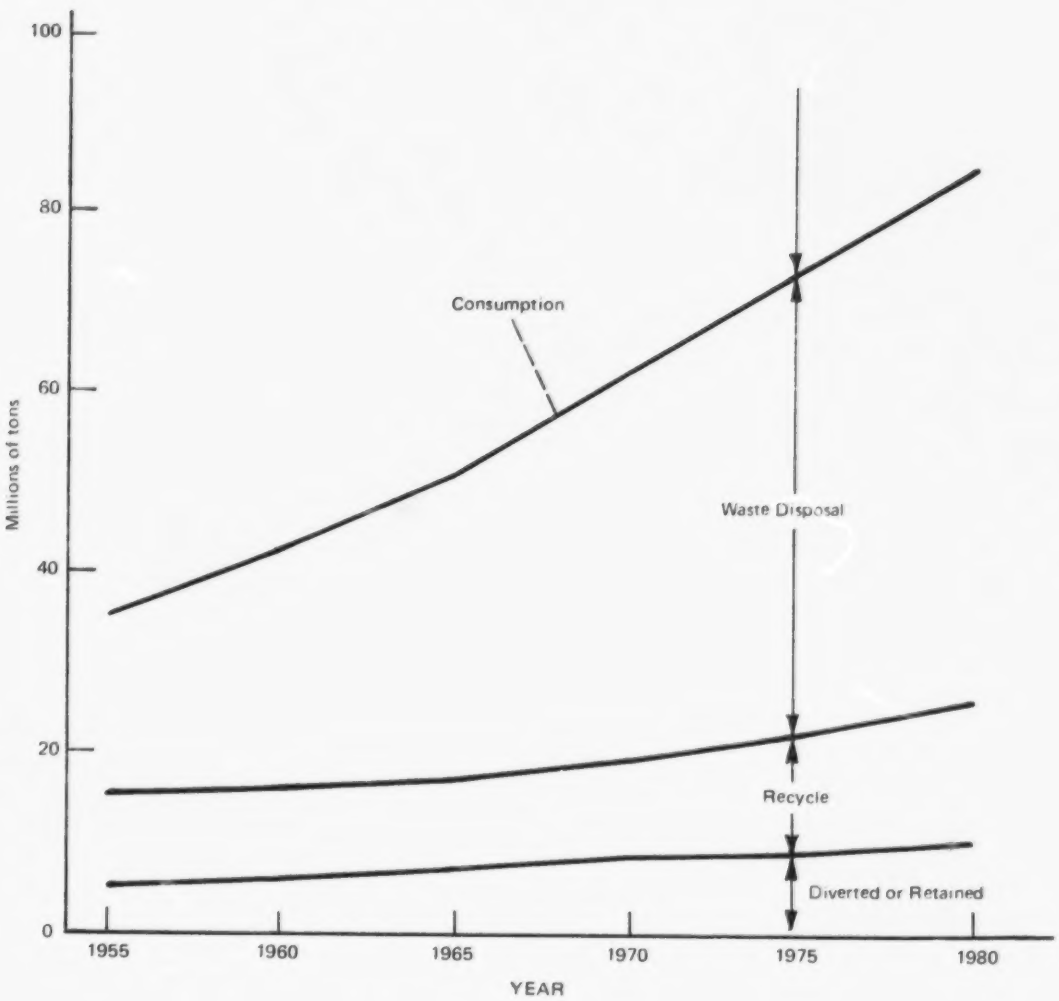


Figure A-1. Paper trends: consumption, disposal, and recycling.*

*Source: Darnay, A., and W. E. Franklin. Salvage markets for materials in solid wastes. Washington, U.S. Government Printing Office, 1972. Ch.IV.

TABLE A-1

WASTEPAPER RECOVERY BY GRADE AND SOURCE IN 1967*
(thousands of tons)

| Grade | Residential | Commercial | Converting | Total |
|---|---|---|---|---|
| Mixed | 70 | 1,860 | 850 | 2,780 |
| News | 1,610 | 50 | 345 | 2,005 |
| Corrugated | -- | 2,300 | 998 | 3,298 |
| High grades | -- | 200 | 1,841 | 2,041 |
| Total | 1,680 | 4,410 | 4,034 | 10,124 |
| Percent of all wastepaper recovery | 16.6 | 43.6 | 39.8 | 100.0 |

*Source: Darnay, A., and W. E. Franklin, Salvage markets for materials in solid wastes, Washington, U.S. Government Printing Office, 1972. p.45-23.

Note: Net exports add another 176,000 tons derived from converting operations.

commercial establishments in high concentrations with few contaminants.

Additional quantities of waste are potentially recoverable from residential and commercial sources. Based on Midwest Research Institute (MRI) estimates, in 1967 there were 35.2 million tons of paper discarded as waste but not recovered: 6.3 million tons were newspapers; 8.6 million tons were corrugated; and 20.3 million tons were all other types.[20] Of course, not all of this waste is potentially recoverable. A portion of the waste is discarded in rural or remote locations and will never be practicably recoverable. A portion is lost in litter or is burned, and a portion would be unusable for technical reasons. The MRI study estimated that the recoverable volume is most likely 10.2 million tons, or 29 percent of the presently unrecovered paper waste (Table A-2). Recovery of this additional amount would have meant an increase in recycling of over 100 percent in 1967.

Approximately half of the additional recoverable tonnage is made up of newspapers and corrugated board, two grades already recovered in substantial quantities. The recycling of these wastes can be facilitated by creating a demand for materials so that they will be collected before being discarded. Prior separation and separate collection of these wastes holds the possibility of a relatively quick and efficient means of increasing the recycling of substantial quantities of wastes.

The remainder of the tonnage that is potentially recoverable is mixed paper, which would require further processing before recycling.

A promising technology for recovery of paper from mixed residential waste has now been developed, however. This is the wet pulping process developed by the Black-Clawson Company that is being demonstrated in an Environmental Protection Agency project in Franklin, Ohio. In this process, about 400 pounds of paper fiber is recovered from each ton of mixed waste input. Ferrous metals and glass are also recovered during processing. The economic feasibility of large-scale plants of this type looks promising.

*Markets*

From a waste-utilization point of view, the paper industry is made up of an integrated segment that primarily uses woodpulp and an independent segment that primarily uses wastepaper (called paperstock by the industry). Most recycling takes place in the independent sector. Major products made from paperstock -and these are major products of the

TABLE A-2

ADDITIONAL WASTEPAPER RECOVERY POTENTIAL FROM SOLID WASTE IN 1967[a]
(million of tons)

| | Unrecovered and discarded as waste | Most likely recoverable | Recoverable as a % of presently unrecovered paper waste |
|---|---|---|---|
| Newspapers | 6.3 | 2.2 | 35.0 |
| Corrugated | 8.6 | 3.0 | 35.0 |
| All other | 20.3 | 5.0 | 24.6 |
| Total | 35.2 | 10.2 | 29.0 |

[a]Source: Darnay, A., and W. E. Franklin, *Salvage markets for materials in solid wastes*. Washington, U.S. Government Printing Office, 1972, p.45-24.

independent segment include combination board (e.g., cereal, detergent, and shoe boxes), deinked newspapers, and construction paper.

Figure A-2 shows the consumption of wood pulp and paperstock in the three major product grades of the paper industry: paper, paperboard, and construction paper and board. Paperboard accounts for 79.4 percent of paperstock consumption; paper for 13.4 percent; and construction paper, for 7.2 percent of the total paperstock consumed. Thus, paper recycling is closely tied to trends in combination board consumption.

Combination board production has grown at a substantially slower rate than that of its direct competitor, solid wood pulpboard, which is made almost entirely from virgin pulp. From 1959 to 1969, total paperboard production increased by 65 percent; solid wood pulpboard, by 112 percent; and combination board, by only 5 percent.[24] Herein lies the major reason for the decrease in the wastepaper recycling ratio.

There has been only one major new market for wastepaper in recent years, the deinking of old newspapers to make newsprint. Newspaper deinking is a very promising market for old news, and increased newspaper recycling will be influenced strongly by this market.

*Issues and Problems*

There are many interrelated factors that have contributed to the decline in the percentage of paper recycled; however, the two primary direct causes are the lack of new markets and the declining share in the combination board market.

It is technically feasible to substitute paperstock for woodpulp in many paper products (Table A-3); however, this is not practiced extensively because of economic factors and the present high reliance of the dominant integrated industry on virgin pulp. Key items that discourage use of wastepaper are discussed in the following paragraphs.

*Logistics.* Paper must be collected from diverse sources, transported to a processor, and then transported to a consuming mill. Combination board mills are usually within reasonable distances of wastepaper sources, but the integrated mills are generally located in the South or West, near forests, but far from cities, where waste is generated. Thus, the high costs of collection and transportation work to the detriment of paper recycling.

*Contaminants.* Contaminants in wastepaper have affected recycling economics unfavorably, and they have also influenced industry orientation. Separation of wastepaper by grade and removal of

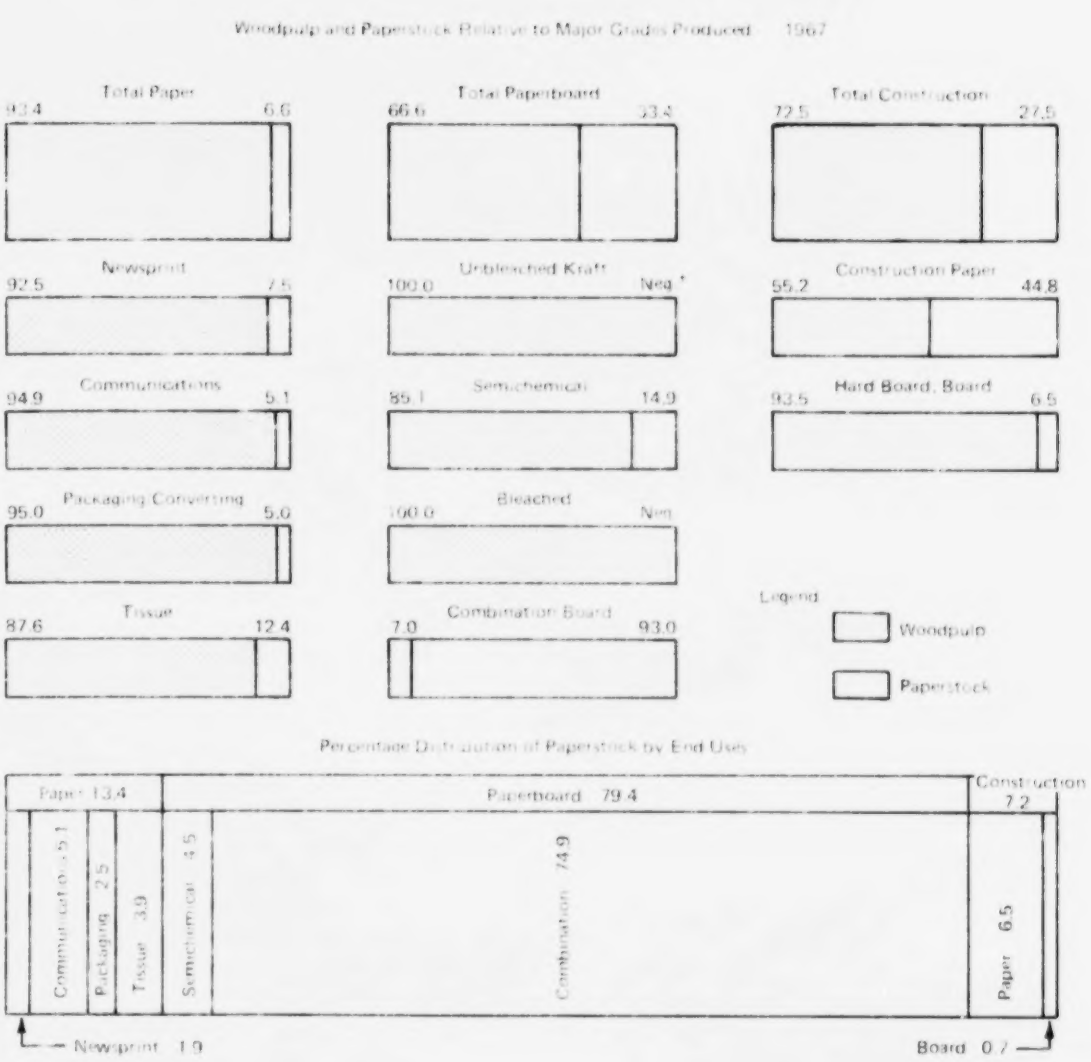


Figure A-2. Relative importance of woodpulp and paperstock in paper, 1967.*

Note: Other fibrous materials were excluded, expressed as percent of total woodpulp and paperstock. Based on MRI estimates.

*Small percentage of paperstock used but cannot be verified in statistics.

*Source: Darnay, A., and W. E. Franklin, Salvage markets for materials in solid wastes, Washington, U.S. Government Printing Office, 1972, p.45-2.

TABLE A-3

TECHNICAL LIMITS FOR RECYCLED MATERIAL FROM PAPER AND PAPERBOARD*

| Material | Recycle limits (% paperstock) |
|---|---|
| Paperboard: | |
| Unbleached kraft | 10–25 |
| Semichemical pulp | 100 |
| Bleached kraft | 5–15 |
| Combination board | 90–100 |
| Paper: | |
| Newsprint | 100 |
| Office, communications | 10–80 |
| Publishing, printing, converting | 10–80 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

contaminants are labor intensive and thus costly.

*Prices.* Waste paper prices have a history of wide fluctuation due to the relative rigidity of supplies and the marginal costs of acquiring new supplies in periods of upswinging demand.

*Technology.* Improvements in woodpulping technology have enabled the paper industry to tap abundant virgin raw materials at increasingly lower costs.

*Integration.* Most papermills own their own forests, and most paper equipment installed since 1945 has been woodpulp based and located close to these virgin raw materials. The mills are designed as continuous operations starting with wood, going into pulp, and ending with the finished product. Through this integration, papermills have also been able to exercise control over the supply and price of their raw materials.

*Tax Treatments.* The cost of virgin woodpulp can be kept down significantly by two tax treatments: a cost depletion allowance (credit against income taxes, based on timber owner's invested capital in a forest and percentage of reserves sold) and a capital gains allowance (profit from sales of timber treated as a capital gain if the timber has been owned for more than 6 months).

### *Economics*

Most of the above problems have a negative effect on the economics of wastepaper use. If one examines the economics of using wastepaper in the manufacture of certain paper and board products, it is obvious that increasing the amount of paperstock in these products increases the cost of manufacturing them.

Table A-4 shows the comparative economics of using supplemental wastepaper in existing papermills for certain products. These examples are by no means exhaustive of the many paper industry products, but these cases support what would seem to be obvious from the current industry orientation. The cost penalty for increasing the use of paperstock is $2.50 per ton for corrugating medium, $3.75 per ton for linerboard (these are the materials used to make corrugated boxes), and $20 to $30 per ton for printing/writing paper. The latter cost differential is the result of the substantial upgrading of wastepaper that would be required to produce a product of the present high standards. The cost of newsprint manufacture, however, is lowered by using 100 percent recycled fiber (deinked newsprint). This has been the only major new market for wastepaper in recent years.

The economics of constructing new mills based on either virgin or secondary fibers also supports industry's trend toward the use of more virgin fiber at the expense of secondary fiber. An analysis of folding boxboard (combination board made from secondary fiber versus solid wood pulpboard made from virgin pulp) found that the return on investment from a virgin-based plant was 8.1 percent, whereas that from a plant based on wastepaper (combination board) was only 4.5 percent.[22] Under such circumstances, investments in new combination board mills are very unlikely. The reason for the shift in recent years of boxboard manufacture from combination board mills to virgin-based mills is obvious.

TABLE A-4

COMPARATIVE ECONOMICS OF PAPER MANUFACTURE FROM RECYCLED AND VIRGIN MATERIALS*

| Product | Linerboard | Corrugating medium | Printing/writing paper | Newsprint |
|---|---|---|---|---|
| Baseline case (recycled fiber content) (%) | 0 | 15 | 0 | 0 |
| Baseline average operating cost ($/ton) | 78.50 | 79.50 | 80–120 | 125 |
| Supplemental fiber use (recycled fiber content) (%) | 25 | 40 | 100 | 100 |
| Operating cost with increased use of recycled fiber ($/ton) | 82.25 | 82.00 | 100–150 | 98 |
| Net cost of increased recycled fiber usage ($/ton) | 3.75 | 2.50 | 20–30 | 27 |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

## FERROUS METALS

### *Status and Trends*

Ferrous solid waste, primarily in the form of food and beverage containers and discarded consumer appliances, constitutes 7 to 8 percent of collected municipal solid waste and totaled roughly 14 million tons in 1970. However, a much more sizable amount of used and discarded ferrous products (an estimated 38 to 54 million tons) is generated annually and appears on our landscape in such visible forms as abandoned automobiles, discarded farm implements, out-of-service rail cars, construction and demolition waste, and other steel products.[2,3,24]

In 1967, American industry consumed about 85.4 million tons of iron and steel scrap, and 7.6 million tons were exported (Table A-5). The domestic scrap consumption represented about 65 percent of the raw steel production (Figure A-3). Fifty million tons of this domestic scrap consumption was "home" scrap that was generated in the ironmaking and steelmaking process and was fed back into the furnaces. Excluding home scrap and exports, 35 million tons of scrap, or about 20 percent of the iron and steel consumption, was recycled in 1967.

For the past 25 years, scrap as a percent of total metallic input to steelmaking has remained essentially constant. However, the amount of this scrap that is purchased by the steel industry (originating from outside the steel plant) has been decreasing slightly, while that generated within the steel mills has increased. As shown in Figure A-4, purchased scrap as a percent of total scrap input to steelmaking has decreased from 44.9 percent for the period 1949-53 to 40.0 percent for 1964-68. In absolute terms, while total steel production increased 35 percent over the period 1950-69 and total scrap consumption increased 30 percent, purchased scrap increased only 8 percent.

TABLE A-5

U.S. IRON AND STEEL SCRAP CONSUMPTION IN 1967*

| Type | Amount (millions of short tons) |
|---|---|
| Domestic scrap consumption: | |
| Home scrap | 50.2 |
| Purchased scrap: | |
| Prompt | 13.6 |
| Obsolete | 21.4 |
| Exports | 7.6 |
| Total | 93.0 |

*Source: Darnay, A., and W. E. Franklin, Salvage markets for materials in solid wastes, Washington, U.S. Government Printing Office, 1972, p.49 and 58-11.

### *Sources of Waste*

There are two basic types of iron and steel scrap: home and purchased scrap. Home scrap, the ferrous waste product generated during iron and steel production, includes ingot croppings, sheet trimmings, and foundry gates and risers. Because it is generated in the steel mill, the scrap is of known composition and purity, and the total amount generated is normally consumed. Home scrap represented 60 percent of the domestic scrap consumption in 1967.[25]

Purchased scrap is further classified as "prompt" or "obsolete." "Prompt" industrial scrap is generated by metalworking firms in their fabrication of products. Standard procedures have been developed for the recycling of prompt scrap, and it never really enters the waste stream. At least 90 percent of the available prompt scrap is estimated to be recycled. The scrap is desirable because of its known composition, condition, and freedom from contaminants. In addition, it is considered a reliable material source because the quantities available are predictable and because recycling channels have been established. Prompt scrap represented about 16 percent of the domestic scrap consumption in 1967.[23]

"Obsolete" scrap comes from discarded iron and steel products. Major sources are structural steel from building demolitions, ships, railroad equipment, and abandoned motor vehicles. Ferrous solid waste, of course, occurs in many other forms, such as food and beverage cans and home appliances, which are not generally recovered because of logistics, contamination, or other factors. Obsolete scrap represented

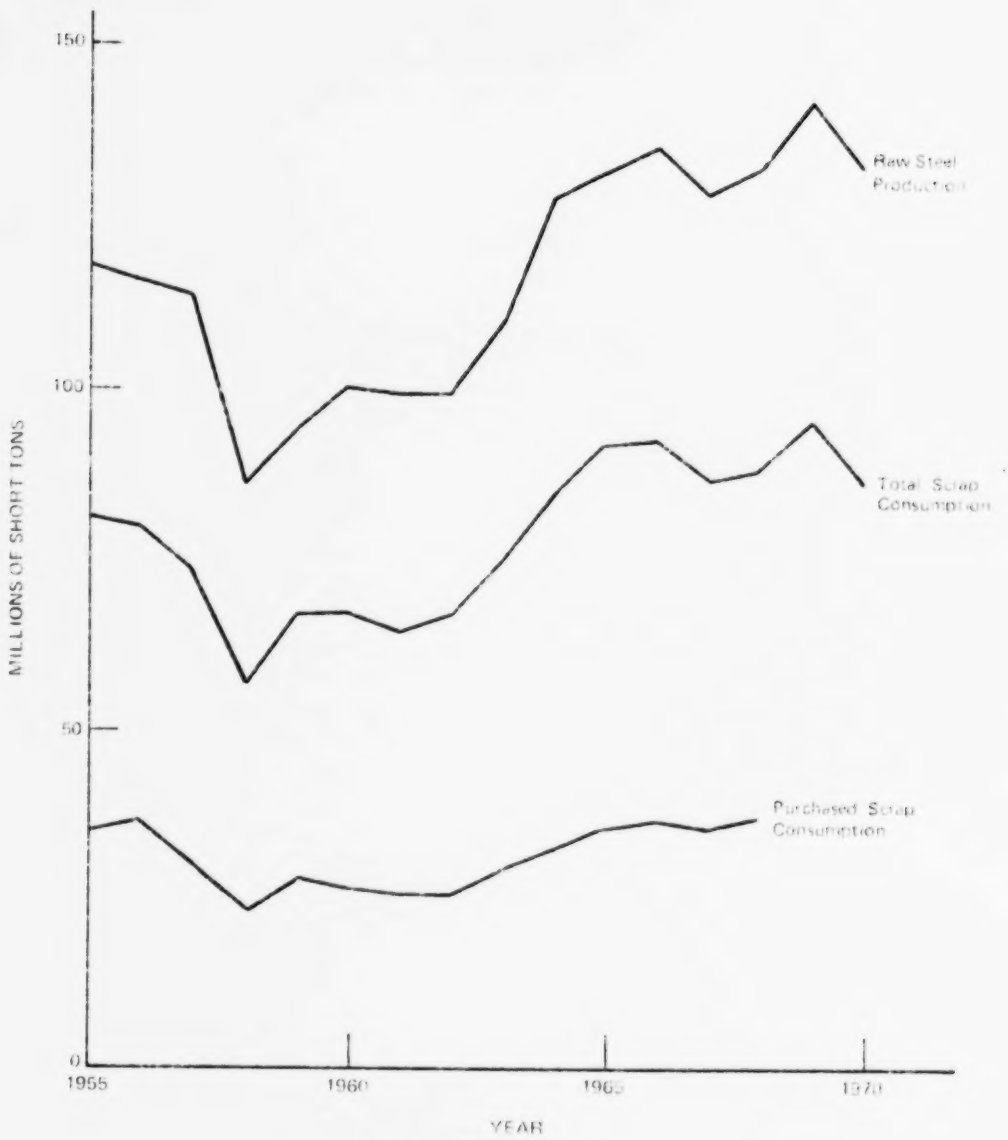


Figure A-3. Domestic raw steel production and scrap consumption.*

*Source: Darnay, A., and W. E. Franklin. Salvage markets for materials in solid wastes. Washington, U.S. Government Printing Office, 1972. p.58-1 and 58-11

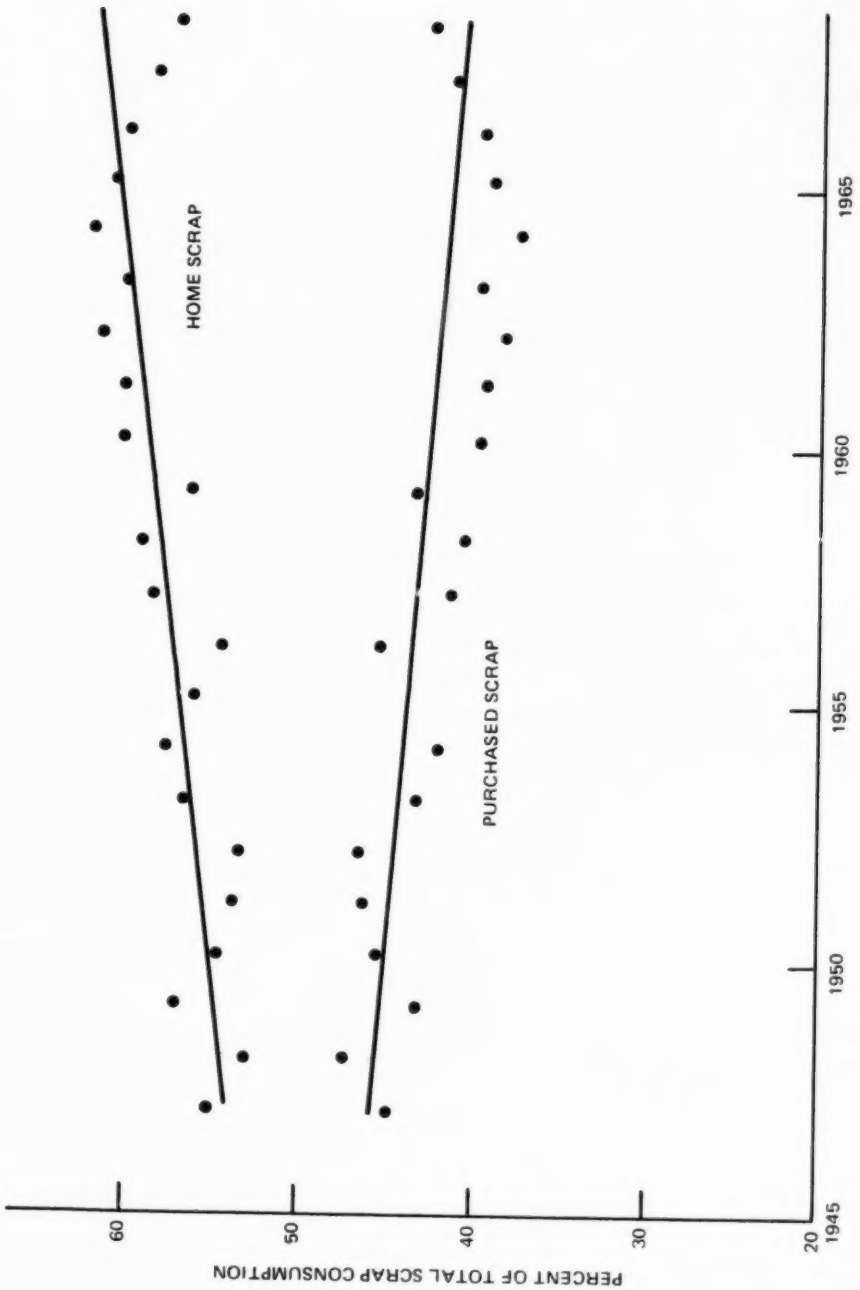


Figure A-4. Domestic home and purchased scrap consumption.*

*Source: Darnay, A., and W. E. Franklin. Salvage markets for materials in solid waste. Washington, U.S. Government Printing Office, 1972. p.58-11.

about 25 percent of the domestic scrap consumption in 1967.[15]

Not all of the steel consumed flows immediately into the waste stream and is available as scrap. Considerable portions go into semipermanent use (buildings, machinery, etc.) and enter the waste stream years later. It is estimated that the 21.4 million tons of obsolete scrap purchased or exported in 1967 was 43 to 56 percent of that available in the solid waste stream. Taking into account scrap located in remote locations and probably not recoverable as well as scrap disposed by individuals, it is estimated that roughly another 24 to 39 million tons of ferrous scrap could feasibly have been recovered in 1967.[23]

### Markets

The major markets for iron and steel scrap are the domestic steel industry, the domestic foundry industry, and exports. In 1969, the percent of total scrap consumption by each was 73.8, 17.5, and 8.7, respectively.[26] However, in terms of purchased scrap, both prompt and obsolete, foundries and exports weigh more heavily. For the steel industry, about 35 percent of scrap consumed is purchased, whereas foundries purchase about 60 percent of their scrap consumption, and exports are, of course, purchased scrap.

The American steel industry is composed of approximately 110 companies; of these, 21 are fully integrated (coke ovens, blast furnaces, and steelmaking furnaces); 9 operate mostly blast and 80 operate only steelmaking furnaces, with electric steelmaking predominating. These 80 companies currently produce less than 10 percent of the Nation's steel output, but they are a significant outlet for ferrous solid waste.

The type of furnace used in steelmaking has a direct bearing on scrap usage. Three types of furnaces are used: open hearth, which uses an approximately 45-percent scrap charge; basic oxygen, 30-percent scrap charge; and electric, 100-percent scrap. (These charges are based on standard operating conditions, which take into account both technological and economic factors.) Basic trends have included (1) the decline of the open hearth from 87 percent of steel production in 1960 to 50 percent in 1968; (2) rapid rise of basic oxygen furnaces from 3.3 percent of production in 1960 to 37.1 percent in 1968; (3) moderate growth of electric furnace steel production, 8.4 percent in 1960 to 12.7 percent in 1968. To date, declines in scrap requirements from decreased open hearth steelmaking have been balanced by increased scrap needs from rising electric furnace production.

In the foundry industry, scrap already accounts for about 85 percent of the metallic input, and product specifications dictate that pig iron be a portion of the charge in some cases. The cupola furnace, which uses an 84-percent scrap charge, dominates; it comprises about 90 percent of the furnaces. Electric furnaces, which make up most of the remainder and which use scrap 100 percent, have been making inroads, however. The potential for increased scrap consumption by foundries is limited, but factors such as the increasing trend toward replacing cupola facilities with electric furnaces, geographic dispersion of foundries to put them closer to scrap sources, and a growth rate in excess of domestic steel production indicate that use of scrap by foundries should at least hold its own and may increase slightly. However, foundries do not have potential as major markets for increased scrap consumption.

Exports are a significant market for iron and steel scrap, constituting 24 percent of total purchased steel in 1970. Exports are particularly important for the movement of obsolete scrap, because a large portion of the exports are from obsolete sources. Japan is the largest consumer of export scrap, taking 48.8 percent of the market in 1970.

Copper precipitation is the major market for steel can scrap at present, but it is quite limited. Only about 300,000 to 400,000 tons of old steel cans and canmaking wastes—a small percentage of the estimated 5 million tons of cans produced each year—are consumed annually by this market.[27]

### *Issues and Problems*

*Differential Tax Treatment.* Iron ore enjoys a 15-percent depletion allowance; in addition, iron ore producers are allowed to use certain capital costs as current deductions. Both of these policies reduce tax liability and, thus, the price at which the ore must be

sold to maintain a given profit level. For example, the 15-percent depletion allowance permits a 13.5-percent decrease in the selling price without reducing the profit to the producer. The percentage depletion allowance continues as long as income is derived from the property, which is usually long after the capital investment in the property has been recovered. Thus, iron ore producers enjoy a major tax subsidy that is not available for secondary material processors.

*Steel Industry Structure.* The integrated portion of the steel industry is iron ore oriented and has a significant investment in ore-processing equipment. The integrated steel manufacturers generally own virgin raw material sources and are able to exercise control over supply and price. Uncertainties in scrap price and availability are inconsistent with the steel industry's practices of long-range planning and long-term commitments to equipment and raw materials.

*Scrap Quality.* Rigid steel production specifications require that scrap be processed to remove contaminants and impurities. Home and prompt scrap are from known sources and are generally higher in quality than obsolete scrap, with the exception of certain obsolete scrap such as rail, ship, and structural scrap. Cans present a special problem because of their contamination with tramp elements: aluminum from tops, lead from the seams, and tin. For example, lead can be harmful to furnace refractories, and too much tin causes undesirable properties in finished steel. Thus, except in periods of peak demand or hot metal shortages, the availability and low cost of higher quality raw materials tend to reduce the steelmaker's incentive to use the lower quality portion of obsolete scrap.

*Changing Ironmaking and Steelmaking Technology.* The replacement of open hearth furnaces by basic oxygen furnaces has tended to reduce scrap requirements. However, the increased usage of electric furnaces has kept total scrap consumption roughly constant overall. Future scrap consumption is tied closely to continued increases in electric furnace melting. Investment decisions depend on the comparative returns on investment from various types of furnaces. The return on investment from an electric furnace that uses 100 percent scrap obviously is strongly influenced by scrap prices.

The technical feasibility of using increasing proportions of scrap in other steelmaking furnaces has been demonstrated. The basic oxygen furnace charge, for example, can be increased by preheating the scrap, but because this entails additional costs, it can only be justified if scrap cost decreases relative to ore cost.

*Logistics.* As with most materials present in solid waste, logistics is a significant deterrent to the recycling of ferrous scrap. Collection and transport from diverse sources is costly. Recycling of large appliances, steel cans, and other ferrous materials in mixed municipal waste is strongly inhibited by high transport costs, relative to scrap value.

*Low Growth Rate of Consuming Industries.* The domestic iron and steel industries are not growing as rapidly as the rest of the American economy, primarily because of increased imports; replacement of steel by other materials; and increased use of lighter, high-strength steels. Over the past decade, while the United States economy has grown at an annual rate of over 5 percent, iron and steel production has grown at an annual rate of about 3 percent.

### *Economics*

Most of the issues add up to an unfavorable economic picture for scrap use in the steel industry, though their individual impact is difficult to measure. The total costs to an integrated steel producer of using steel as opposed to ore in a basic oxygen furnace were estimated by the Midwest Research Institute in a study for the Council on Environmental Quality.[4] The comparative costs are difficult to determine because the steel industry does not maintain, or at least does not report, such figures. Estimates have been made, however, which indicate that the cost of using scrap is slightly higher than the cost of using ore.

The chosen point of equivalency in the production process was the point where either hot molten pig iron or melted scrap could be used to charge a basic oxygen furnace. The total cost of scrap at this point was estimated to be $44.00 per ton, including $33.50 purchased price of the scrap, $6.00 melting cost, $3.50 for scrap handling, and $1.00 for increased refractory wear caused by scrap usage.

Molten pig iron cost was estimated at $37.50 per ton, including $28.50 for the ore and associated raw materials and $9.00 for melting cost. Thus, the cost of scrap ready for charging to a basic oxygen furnace is about $6.50 greater than the cost of hot metal derived from ore at the same point.

The mill operator may actually *perceive* an even higher relative cost of scrap usage because there will be a tendency for him to associate a loss with letting ore reduction facilities already in place sit idle. The mill operator will also associate a cost – in this case, a real one – with the possibility that end products made from scrap may be rejected because they do not meet product specifications.

Thus, without a reduction in scrap cost of at least $6.00 to $7.00 per ton, it is unlikely that the utilization of scrap in basic oxygen furnaces by existing steel mills will increase.

### *Usage Considerations*

The reluctance of the integrated steel industry to risk contamination in situations where specifications are demanding is understandable. However, for the small electric furnace operator serving the crude steel reinforcing bar and not participating in specification steel at all, there is no particular quality problem.

Table A-6 shows how well various steel products are suited for the input of lower grades of scrap, and it shows their tonnage figures and percentages of total output in 1970. Reinforcing bars and hot-rolled light shapes can be produced from miscellaneous waste scrap, with no significant sacrifice in properties. In plants producing a considerable variety of products, including high-specification items, low grade scrap would be unattractive even at low prices; the trend is to produce steel furnace output that can meet a wide range of product specifications, and low grade scrap could result in lower quality home scrap.

The total market for reinforcing bars and light-shape raw materials would be sufficient to handle the gatherable supply of low grade ferrous scrap if all these products were produced by electric minimills. There is, in fact, a reasonably good fit between the ferrous solid waste problem and the minimill requirements – in price, materials, and geography. However, the large integrated steel producers also have a share in the reinforcing bar and shape markets, and as stated above, they are reluctant to use the lower scrap grades.

TABLE A-6

STEEL PRODUCT SUITABILITY FOR INCLUSION OF LOW GRADE SCRAP*

| Product | 1970 net tons shipped (millions) | Percent of 1970 shipments | Suitability of low grade scrap as ingredient |
|---|---|---|---|
| Reinforcing bars | 4.891 | 5.4 | Excellent |
| Selected hot-rolled light shapes | 6.076 | 6.7 | Excellent |
| Selected wire rods | 1.607 | 1.8 | Very good |
| Selected rail accessories | .440 | .5 | Very good |
| Selected plates | 7.777 | 8.6 | Good |
| Oil country goods | 1.307 | 1.4 | Fair |
| Heavy structural shapes | 5.566 | 6.1 | Fair |
| Steel piling | .495 | .5 | Fair |
| Hot-rolled strips | 1.293 | 1.4 | Marginal |
| Hot-rolled sheet | 12.319 | 13.6 | Marginal |
| All other products | 49.027 | 54.0 | Generally unsuitable |
| Total | 90.798 | 100.0 | – |

*Source: Midwest Research Institute. Economic studies in support of policy formation on resource recovery. Unpublished report to the Council on Environmental Quality, 1972.

## NONFERROUS METALS

In 1969, a total of 10.5 million tons of aluminum, copper, lead, and zinc were consumed in the United States, and 3.2 million tons were recycled, an average of 30 percent of consumption. Figures A-5 through A-8 show consumption and amount of these materials recycled from 1960 to 1969. For 1969, recycling as a percent of consumption for each was 23 percent for aluminum, 46 percent for copper, 44 percent for lead, 10 percent for zinc.[28]

Approximately 24 percent of the aluminum and only about 4 percent of all the other major nonferrous metals consumed occur in municipal waste. These four metals constitute less than 1 percent, or roughly 1.2 million tons, of the municipal solid waste collected in 1968. Aluminum accounted for 83 percent of this total.[29]

### *Sources and Markets*

Table A-7 shows the amounts of each of the nonferrous metals recovered from prompt and obsolete sources. Copper and lead recovery from obsolete sources is a very important part of recovery, whereas for aluminum and zinc, little of the recovered scrap comes from obsolete sources. In all cases, virtually all of the available prompt scrap from industrial fabrication is recovered. Recovery of the metals from obsolete sources is directly related to the form in which the scrap occurs and to its location. Thus, large quantities of lead are recovered from wornout batteries returned to dealers by consumers. Obsolete zinc, which is widely scattered and usually appears in small quantities and in combination with other materials, is largely unrecovered.

The aluminum can recycling programs of aluminum producers and soft drink producers have been the most visible efforts to reclaim aluminum from municipal waste. In 1970, these programs resulted in the removal of about 2,875 tons of aluminum from the solid waste stream. This was 1.3 percent of the quantity of aluminum cans reaching the market.[30]

The feasibility of these programs depends on the continued voluntary delivery of aluminum cans to the centers at no more than $200 per ton. Thus far, this price has proved to be sufficient incentive to persuade individuals, Boy Scout groups, and others to collect cans and bring them to the centers. One of the major aluminum manufacturers participating in the recycling program has estimated that the quantity of aluminum cans ultimately recoverable by this method will be between 5 and 30 percent of that reaching the market.

TABLE A-7

AMOUNT OF NONFERROUS METALS RECOVERED FROM PROMPT AND OBSOLETE SOURCES IN 1969*

| Material | Source | Amount recycled (thousands of tons) |
|---|---|---|
| Aluminum | Obsolete | 175 |
| | Prompt | 855 |
| Copper | Obsolete | 657 |
| | Prompt | 832 |
| Lead | Obsolete | 497 |
| | Prompt | 88 |
| Zinc | Obsolete | 41 |
| | Prompt | 141 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2, v.2. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

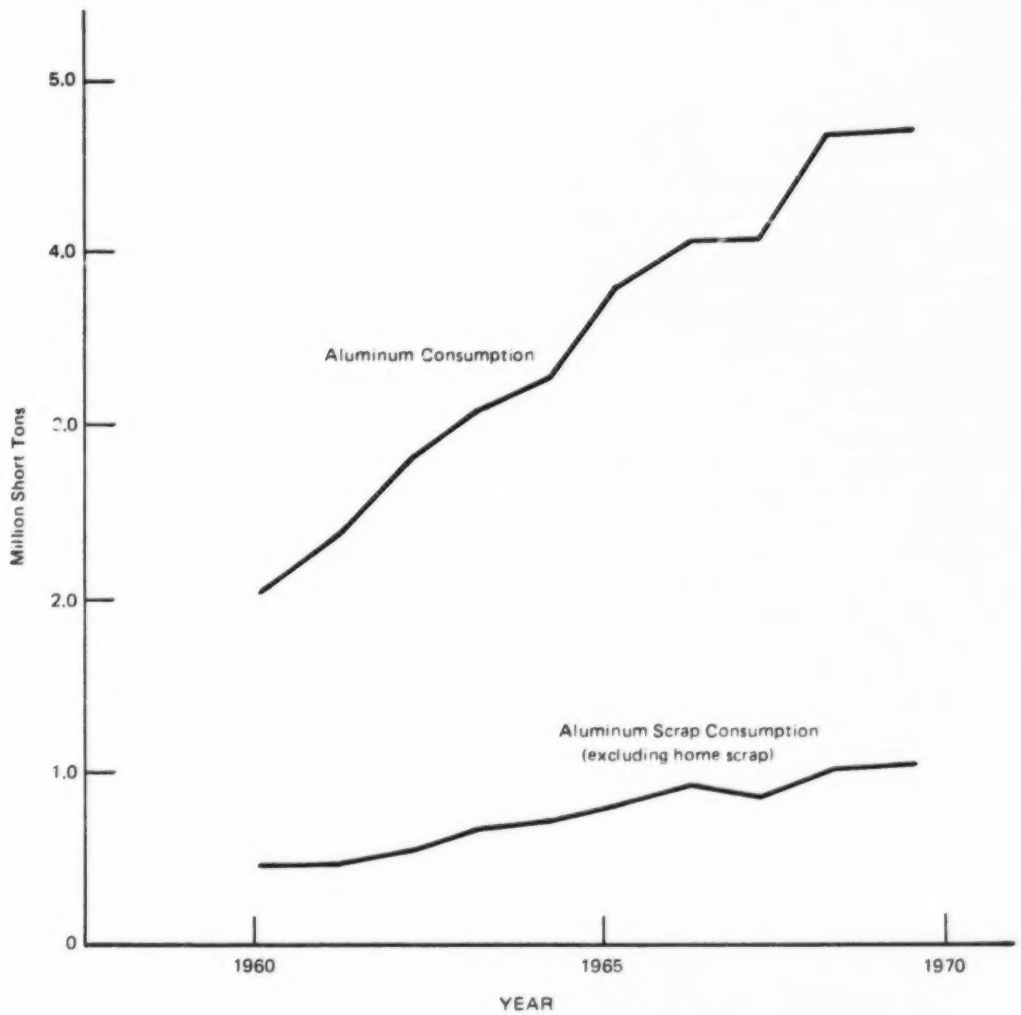


Figure A-5. Aluminum and aluminum scrap consumption.*

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 1, v.2. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 729.)

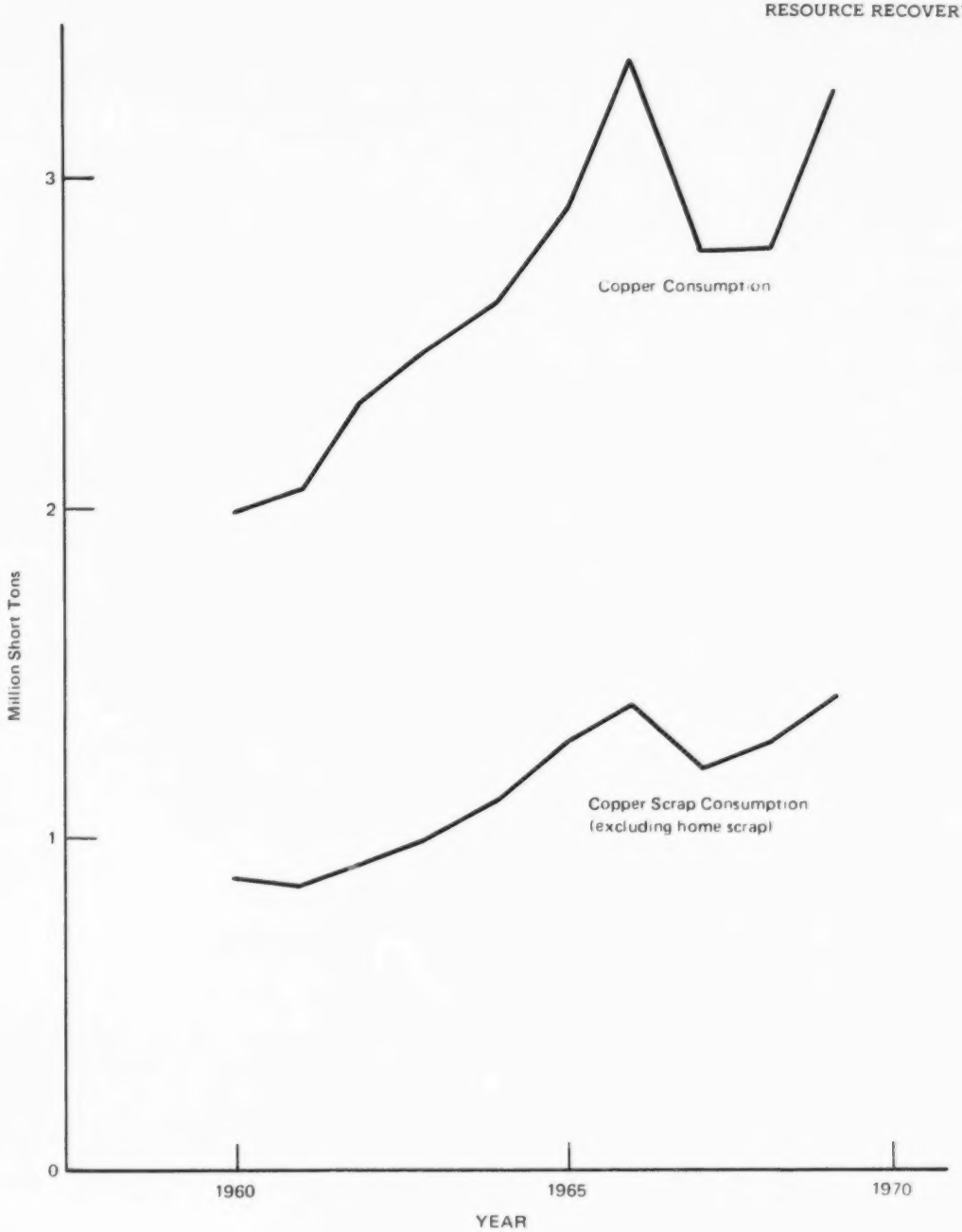


Figure A-6. Copper and copper scrap consumption.*

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2. v.3. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

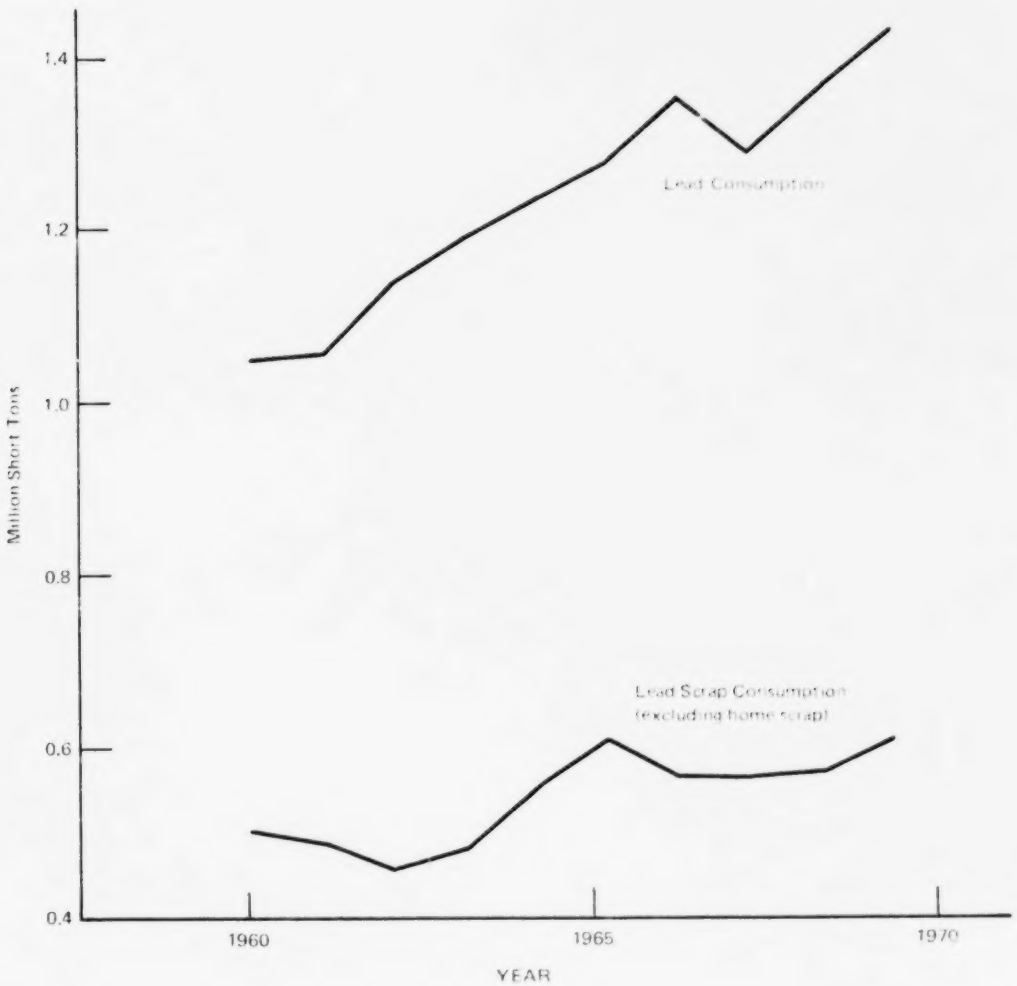


Figure A-7. Lead and lead scrap consumption.*

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2. v.4. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

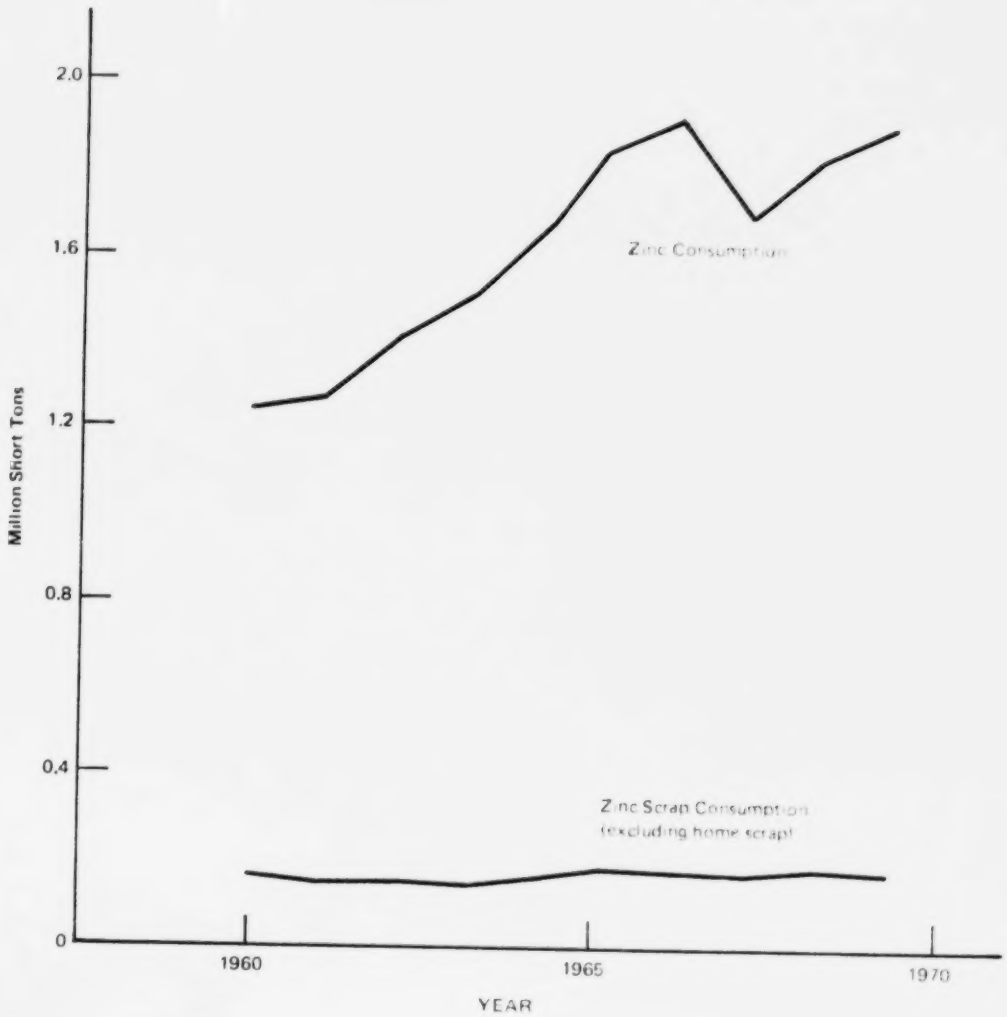


Figure A-8. Zinc and zinc scrap consumption.*

*Source: Battelle Memorial Institute, Columbus Laboratories, A study to identify opportunities for increased solid waste utilization, Book 2, v.4, U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

The major sources and markets for recycled aluminum, copper, lead, and zinc, in terms of product type, are shown in Tables A-8 to A-15.

*Issues and Problems*

Nonferrous metals are high-value materials for which a steady demand exists. Compared to paper, steel, glass, textiles, and plastics, the costs of collecting, transporting, and processing nonferrous metal scrap are not as high a percentage of its value. In addition, costs of refining virgin nonferrous metals are high. Because handling nonferrous scrap does not increase costs inordinately, the scrap is considerably cheaper than virgin material. Thus, the scrap moves freely.

Probably the major reason that more nonferrous scrap is not recycled is the form and location in which it occurs. Most of the nonferrous scrap that is easily accessible is recycled. However, there are certain types of scrap that are too contaminated and too widely scattered to allow economical recovery, despite the high value of the materials (dealers buying prices range from $60 to $920 per ton). For example, copper in cartridge brass and lead in ammunition are usually widely scattered over the countryside. Zinc is usually used as an alloying agent and coating and thus is extremely difficult to separate. Aluminum occurring in consumer durables, transportation vehicles, and construction is often only a small part of the product, thus much of it is never recovered. Aluminum used in packaging and ending up in the municipal waste stream cannot be economically recovered at present. It could only be feasibly separated as part of a large reclamation system where other materials that constituted a higher percentage of the waste are also recovered.

An interesting perplexity of nonferrous metal recycling is that for some of the metals - copper is a good example - the scrap dealers perceive that they are pulling in about all that is available. Their estimate of the recycling ratio would be much higher than the actual.

TABLE A-8

SOURCES OF OBSOLETE ALUMINUM SCRAP IN 1969*

| Source | Estimated available for recycling (thousands of tons) | Estimated amount recycled (thousands of tons) | Percent recycled |
|---|---|---|---|
| Building and construction | 71.0 | 9.0 | 13.0 |
| Transportation | 329.0 | 100.0 | 30.0 |
| Consumer durables | 197.0 | 25.0 | 13.0 |
| Electrical | 7.0 | 6.5 | 93.0 |
| Machinery and equipment | 61.0 | 15.0 | 25.0 |
| Containers and packaging | 486.0 | 2.0 | 4 |
| Other | 183.0 | 17.5 | 9.2 |
| Total | 1,334.0 | 175.0 | 13.1 |

*Source: Battelle Memorial Institute, Columbus Laboratories, A study to identify opportunities for increased solid waste utilization, Book 2, v.4, U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-9

MARKETS FOR PROMPT AND OBSOLETE ALUMINUM SCRAP IN 1969*

| Use | Scrap consumption (thousands of tons) | Percent |
|---|---|---|
| Casting alloys | 741 | 69 |
| Wrought aluminum products | 255 | 24 |
| Exports | 77 | 7 |
| Total | 1,073 | 100 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2. v.2. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-10

SOURCES OF OBSOLETE COPPER SCRAP IN 1969*

| Source | Estimated available for recycling (thousands of tons) | Estimated amount recycled (thousands of tons) | Percent recycled |
|---|---|---|---|
| Electrical wire and copper tube | 471.0 | 319.4 | 68 |
| Magnet wire | 158.0 | 13.5 | 9 |
| Cartridge brass | 112.1 | 35.4 | 31 |
| Automotive radiators | 53.0 | 48.5 | 91 |
| Railroad car boxes | 22.6 | 20.0 | 88 |
| Other brass, cast and wrought | 703.3 | 213.9 | 30 |
| Alloying additives | 96.9 | 0 | 0 |
| Miscellaneous | 6.1 | 6.1 | 100 |
| Total | 1,623.2 | 656.8 | 40 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2. v.2. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-11

MARKETS FOR PROMPT AND OBSOLETE COPPER SCRAP IN 1969*

| Use | Scrap consumption (thousands of tons) | Percent |
|---|---|---|
| Wire and cable | 292 | 20 |
| Brass mill products | 701 | 47 |
| Brass/bronze foundries | 389 | 25 |
| Other | 127 | 8 |
| Total | 1,489 | 100 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2, v.3. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-12

SOURCES OF OBSOLETE LEAD SCRAP IN 1969*

| Source | Estimated available† for recycling (thousands of tons) | Estimated amount recycled (thousands of tons) | Percent recycled |
|---|---|---|---|
| Batteries | 485 | 350 | 72 |
| Cable sheathing | 130 | 32 | 25 |
| Solder | 65 | 9 | 14 |
| Bearing metal | 33 | 10 | 30 |
| Type metal | 29 | 29 | 100 |
| Ammunition | 80 | 5 | 6 |
| Other | 100 | 62 | 62 |
| Total | 922 | 497 | 54 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization. Book 2, v.4. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

†271,000 tons of lead used in tetraethyl lead for gasoline and 125,000 tons of lead used in oxides and chemicals are not included because there is no possibility for its recovery.

## TABLE A-13

MARKETS FOR PROMPT AND OBSOLETE LEAD SCRAP IN 1969*

| Use | Scrap consumption (thousands of tons) | Percent |
|---|---|---|
| Type | 28 | 4.8 |
| Tetraethyl lead | 75 | 12.8 |
| Batteries | 400 | 68.4 |
| Solder | 31 | 5.3 |
| Cable | 19 | 3.2 |
| Bearings | 13 | 2.2 |
| Other | 19 | 3.2 |
| Total | 585 | 99.9 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization, Book 2, v.2. U. S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-14

SOURCES OF OBSOLETE ZINC SCRAP IN 1969*

| Source | Estimated available for recycling (thousands of tons) | Estimated amount recycled (thousands of tons) | Percent recycled |
|---|---|---|---|
| Zinc base alloys | 353 | 33 | 9 |
| Old galvanized | 390 | 0 | 0 |
| Oxides and chemicals | 190 | 0 | 0 |
| Other | 130 | 8 | 6 |
| Total | 1,063 | 41 | 3.9 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization, Book 2, v.2. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

## TABLE A-15

MARKETS FOR PROMPT AND OBSOLETE ZINC SCRAP IN 1969*

| Use | Scrap consumption (thousands of tons) | Percent |
|---|---|---|
| Slab zinc | 76 | 41.7 |
| Zinc dust | 34 | 18.8 |
| Alloys | 27 | 14.8 |
| Oxides and chemicals | 45 | 24.7 |
| Total | 182 | 100.0 |

*Source: Battelle Memorial Institute, Columbus Laboratories. A study to identify opportunities for increased solid waste utilization, Book 2, v.5. U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va. as PB 212 730.)

# GLASS

## *Status and Trends*

In 1967 the glass manufacturing industry produced 12.8 million tons of glass. This production was divided among the three major segments of the industry: containers, flat glass, and pressed and blown glass. Containers, the most significant segment, accounted for 8.9 million tons, whereas flat glass accounted for 2.1 million tons and blown glass for only 1.8 million tons.

By weight, glass constitutes only 6 to 8 percent of municipal solid waste. There is virtually no recovery of glass from mixed waste, but a small amount of glass is recycled through voluntary collection centers and cullet dealers. Compared to other materials, glass is among the lowest in recycling ratios, or about 4.5 percent of consumption, when home scrap (scrap generated in the glass manufacturer's plant) is excluded. Of a total of 12.8 million tons of glass produced in 1967, purchased cullet consumption was approximately 580,000 tons.[41]

## *Sources and Markets*

Only a minute portion of glass waste (almost exclusively flat glass) is associated with industrial sources. Thus, municipal waste is the main potential source for old glass for recycling. In 1968, there were about 11.6 million tons of glass in municipal solid waste.

The best sources of quality cullet have been declining. Clear glass milk bottles and returnable glass containers rejected from bottle-washing operation—major sources of cullet in the past—are gradually disappearing. Sorting, collection, and delivery costs have risen, principally because these operations are highly labor intensive. Plants have not been maintained and equipment has not been purchased because of the limited capital of the few dealers still in operation. As the quality and availability of purchased cullet have deteriorated, its use in the glass industry has also declined.

The glass container segment of the industry, which accounts for over 70 percent of the total glass tonnage output, purchased only about 100,000 tons of cullet, or 1 percent of its raw material consumption in 1967. This is significantly lower than in the other two segments of the industry, largely because of increased utilization of in-plant cullet. Flat glass producers purchased 10 percent, or 244,000 tons; and pressed and blown glass producers, 12 percent, or 256,000 tons.[42]

In addition to the use of purchased cullet in glass furnaces, there are several alternatives for cullet utilization. The most widely publicized alternative is in "glasphalt," a road-surfacing material in which cullet replaces part of the asphalt aggregate. Initial testing results at the University of Missouri indicate that glasphalt is equal to or superior to conventional asphalt. However, cullet would have to compete economically with asphalt aggregate, which ranges in price from $1.50 to $5.00 per ton when delivered to the asphalt plant. Present cullet prices are significantly higher than this amount.

Other proposed uses for cullet include construction materials, such as glass-cement blocks, and cullet-terrazzo. Experiments to determine the feasibility of cullet utilization in these products are currently underway.

## *Issues and Problems*

The glass industry has certain characteristics that make high levels of waste recycling much more favorable than in other industries. First, the manufacture of glass containers is essentially a one-step process, starting with raw materials and ending with the finished product. Second, cullet can be substituted for virgin raw materials in large percentages, provided that the cullet meets minimum specifications of color, cleanliness, and purity. From a technology standpoint, glass manufacture from 100 percent cullet appears possible.

There are, however, two problem areas: comparative economics and the recovery of cullet from mixed waste. With respect to economics, the cost of virgin raw materials averages $15.48 per ton batch, as compared to a range of from $16.00 to $22.50 per ton batch of cullet; both include freight charges to the plant. Processing cost differentials are

not significant. The conversion of an existing plant to using increased quantities of purchased cullet would cost from $50,000 to $100,000, depending upon the plant; but the changeover could be accommodated within a framework of normal periodic plant improvements. A new plant designed to use cullet would be no more costly than a new plant designed for virgin materials.[4]

The recovery of large quantities of cullet from municipal waste is dependent on the development of a technical process for separating and upgrading the cullet. However, the possibility of source separation of glass containers in the home for separate collections is an alternative that cannot be eliminated. Neither traditional cullet dealers nor voluntary citizen delivery of glass to recycling centers is likely to increase the cullet flow by more than a few percent.

Mechanical separation methods for removing glass from other components of municipal waste are still under development. One promising system that combines density classification and optical color sorting is currently being tested at Franklin, Ohio; other methods, including one developed by the Bureau of Mines, are not yet ready for a comprehensive test.

Until the technology is further developed, utilization of purchased cullet on a large scale does not appear possible. Further, because glass is only a small percent of solid waste, complete glass recovery from mixed waste is not likely to occur until full-scale recovery centers concerned with all major materials are set up.

Unless source separation of glass containers is found to be feasible, utilization of purchased cullet on a large scale appears to be closely tied to development of full-scale municipal resource recovery centers. The glass coming out of such systems will not be attractive to the glass industry on a cost basis, however, unless economic incentives are provided.

## PLASTICS

### *Status and Trends*

Plastics are becoming an increasingly important material in our society, and their growth continues at an impressive rate. From 1960 to 1970, plastics consumption increased at an average annual rate of 11.8 percent and totaled 8.5 million tons in 1969. By 1980, consumption is expected to reach 19 million tons.[33]

Today plastics account for only about 2 percent by weight of municipal solid waste and, by 1980, will average about 3 percent. Very little plastic scrap is recycled other than that reused within the manufacturing plant in which it is generated. This, however, is a fairly significant quantity. Plastics fabricators, for example, consumed an amount of internal scrap equal to about 1.5 million tons in 1970.[34] There is essentially no recovery of plastic waste from obsolete products.

The plastics reprocessor is the recycling channel for all industrial plastics recycled outside originating plants. About 500,000 tons of waste plastics were handled by reprocessors in 1970. Of the plastics recycled through reprocessors, about 55 percent came from resin producers; 30 percent, from fabricators; and 15 percent, from converters.[35,36]

There are two types of plastics, thermoplastics and thermosetting plastics. The thermosetts, 20 percent of plastics consumption, cannot be softened and reshaped through heating and, thus, are not recyclable. In addition, most of the plastics used as coatings and adhesives are impossible to recycle. Thus, about 75 percent of the plastics consumed are potentially recyclable.

### *Sources and Markets*

Table A-16 shows the major markets for plastics. Packaging and construction are by far the most significant, accounting for 20 and 25 percent, respec-

TABLE A-16

TOTAL AND SELECTED MAJOR END USE MARKETS FOR CONSUMPTION OF PLASTICS, 1967 TO 1969*
(thousands of tons)

| Market | 1967 | 1968 | 1969 |
|---|---|---|---|
| Agriculture | 75+ | 85 | 95 |
| Appliances | 198 | 238 | 234 |
| Construction | 1,070 | 1,215 | 1,327 |
| Electrical | 396 | 452 | 567 |
| Furniture | 250+ | 273 | 328 |
| Housewares | 313 | 373 | 425 |
| Packaging | 1,121+ | 1,508 | 1,729 |
| Toys | 208 | 243 | 269 |
| Transportation | 109 | 334 | 536 |
| Total consumption | 6,550 | 7,558 | 8,535 |

*Source: Darnay, A., and W. E. Franklin, Salvage markets for materials in solid wastes. Washington, U.S. Government Printing Office, 1972. p.88-5.

tively, of consumption in 1970. Plastics from packaging account for about 60 percent by weight of the plastics in the solid waste stream; much of the other plastic consumed is "held up" in permanent and semipermanent end uses. Although some of the waste generated in the various stages of plastics production is recycled, the portion that is not makes up about 15 percent of the plastics in the waste stream. Thus, packaging and industrial waste account for 75 percent of plastic waste.[37]

As a general rule, scrap plastic has to be used in an end application having wider specification requirements than the product yielding the scrap. The primary markets for scrap plastic include such items as hose, weather stripping, toys, cheap housewares, pipe, and similar applications. These are areas where (1) plastic properties and performance are not paramount; (2) relatively noncritical processes are used, such as compression molding or heavy extrusion; (3) the cost of plastic resin is a high proportion of total product cost.

Plastics also have potential as a fuel supplement for generating energy because of their high Btu value of 11,500 Btu per pound. (The Btu content of paper is about 8,000 Btu per pound and that of coal is about 12,000 Btu per pound. This is particularly appealing for the recovery of plastics, or value from plastics, in municipal waste, where plastics are hard to separate from other materials.

*Issues and Problems*

*Technology*. There is a fundamental difference between the nature of plastics recycling and that of metals, paper, glass, and other materials. Metals production, for example, begins with an impure ore that is progressively concentrated, smelted, refined, and freed from impurities. Plastics production, on the

other hand, begins with a high-purity virgin polymer to which various additives, colorants, and reinforcements are added. Thus, in the metals industries, there is a background of technology designed to purify and upgrade ores and concentrates. Such technology can also be applied to the upgrading of scrap. In the plastics industry, where the basic raw material is progressively "contaminated" in production, little technology has been developed that can be applied to purify waste plastics.

*Compatibility.* The principal difficulty in recycling plastics is that different polymers (polyethylene, polyvinyl chloride, etc.) are not compatible with each other and must be separated, a very difficult and costly task.

*Economics.* The continually decreasing cost of basic plastic materials has made scrap plastic less competitive with its main competitor, off-grade virgin resin. For example, since 1961, the price of low-density polyethylene has decreased from 24 to 13 cents per pound. Scrap plastic, which is restricted by rising labor and distribution costs, did not drop as rapidly; the price of the scrap is now only about 1 cent per pound under the off-grade resin price, versus about 3 cents in 1961.

*Logistics.* This problem, which is common to recycling of all materials, is important to plastics recycling. The extremely low density of plastics makes transportation very costly.

*Separation.* Separation of plastics from other waste is extremely difficult, making recovery of plastics from municipal waste almost impossible unless the plastics can be diverted from the waste stream and kept separate.

## TEXTILES

### *Status and Trends*

The U.S. textile industry consumed approximately 5 million tons of textile fiber in 1970, an increase since 1960 of 61.5 percent. Far more significant for textile recycling was the change in the type of fiber consumed, with a major shift occurring from use of natural to manmade fibers. In 1960, natural fibers constituted 69 percent of fiber consumption; manmade fibers, 31 percent. In 1970, the figures were 39 percent for natural fibers and 61 percent for manmade. By 1980, the ratio of natural to manmade fibers is expected to be 25 to 75. The implications of this change will be discussed.[38]

In 1970, an estimated 0.8 million tons of waste textiles were processed by waste textile dealers and sold (recycled) to various markets.[39] In addition, an undetermined amount of used clothing that potentially would enter the waste stream was collected by social welfare agencies and redistributed.

There are not sufficient historical data available to show trends in textile recycling. However, it is known that secondary textile consumption in many traditional markets has been declining and that other markets, such as the important wiping cloth market, have been growing at a slower rate than total textile consumption. Thus, it is almost certain that the rate of textile recovery (waste recovered versus textile consumption) has been declining.

Textiles represent only a small portion of municipal solid waste. In 1968, textiles in collected municipal solid waste totaled 1.2 million tons, or 0.6 percent of the total. Most of the textile consumption that does not appear in the municipal waste stream is either collected by social welfare agencies, disposed of, sent to secondary textile dealers by industry, or is being accumulated in households.

### *Sources and Markets*

Figure A-9 represents the major sources and markets for textile waste. The mill waste is the home scrap of the textile industry; the manufacturing waste, the prompt portion, and consumer discards, the obsolete.

In contrast to most of the other materials discussed in this report, the home scrap (mill waste) is not reused within the generating plant, but instead,

passes through the secondary textile dealers. Mill waste accounted for about one-third of the material handled by waste textile dealers in 1970.

Waste from fabrication (prompt) is a considerably less important source of recycled textile waste than is the case with many other materials. It has been estimated that waste recovered from fabrication is only about 60 percent of that generated.[40] Fabrication waste accounted for an estimated 20 percent of the waste handled by waste textile dealers in 1970.

Obsolete waste accounted for the remaining 45 percent of recycled textile waste. This waste is provided mostly by social welfare agencies and institutions such as Goodwill Industries from items deemed unsuitable for reuse as clothing.

### *Issues and Problems*

The increasing trend toward the use of cotton-polyester and wool-polyester blends probably represents the major problem of textile recycling of the 1970's. These blends are not only generally unusable as wastes in themselves, but they also tend to become mixed with other, usable waste textiles and thereby reduce the economic value of the total waste supply. This has caused problems, particularly in the three major markets for cotton waste: rag paper, vulcanized fiber, and wiping cloths.

In the case of the first two markets, contamination of cotton is limited to a maximum of 1 to 2 percent. Thus, increase in blends means greater control by the textile processors, resulting in increased cost. It also greatly reduced the usable yield from used textiles.

Fiber blends have essentially the same effect on the wiping cloth business. Wipers are less sensitive to small percentages of polyester fiber, but fiber blends with over 50 percent polyester do not have satisfactory absorption characteristics. (Garments with polyester/cotton blends of 50/50 and 65/35 are extremely common.) The present percent of such blends in mixed rag bundles is unknown, but the increased replacement of manmade fibers by synthetics is testimony that they are likely to increase, thereby reducing usable yields.

Another major problem of textile recycling is that used textiles are losing ground in many traditional markets. Wool markets are one of the most serious problems, due mainly to the Wool Labeling Act (the effect has been psychological one, on consumers who perceive that virgin wool is cleaner or purer) and increased competition from secondary wool from foreign sources. Also, virgin-based materials are replacing used textiles in some markets. The incentive for using secondary textiles as paddings, filler, etc., has traditionally been their low cost. Now, development of virgin-based products such as urethane foams at competitive prices has resulted in decreasing used textile markets.

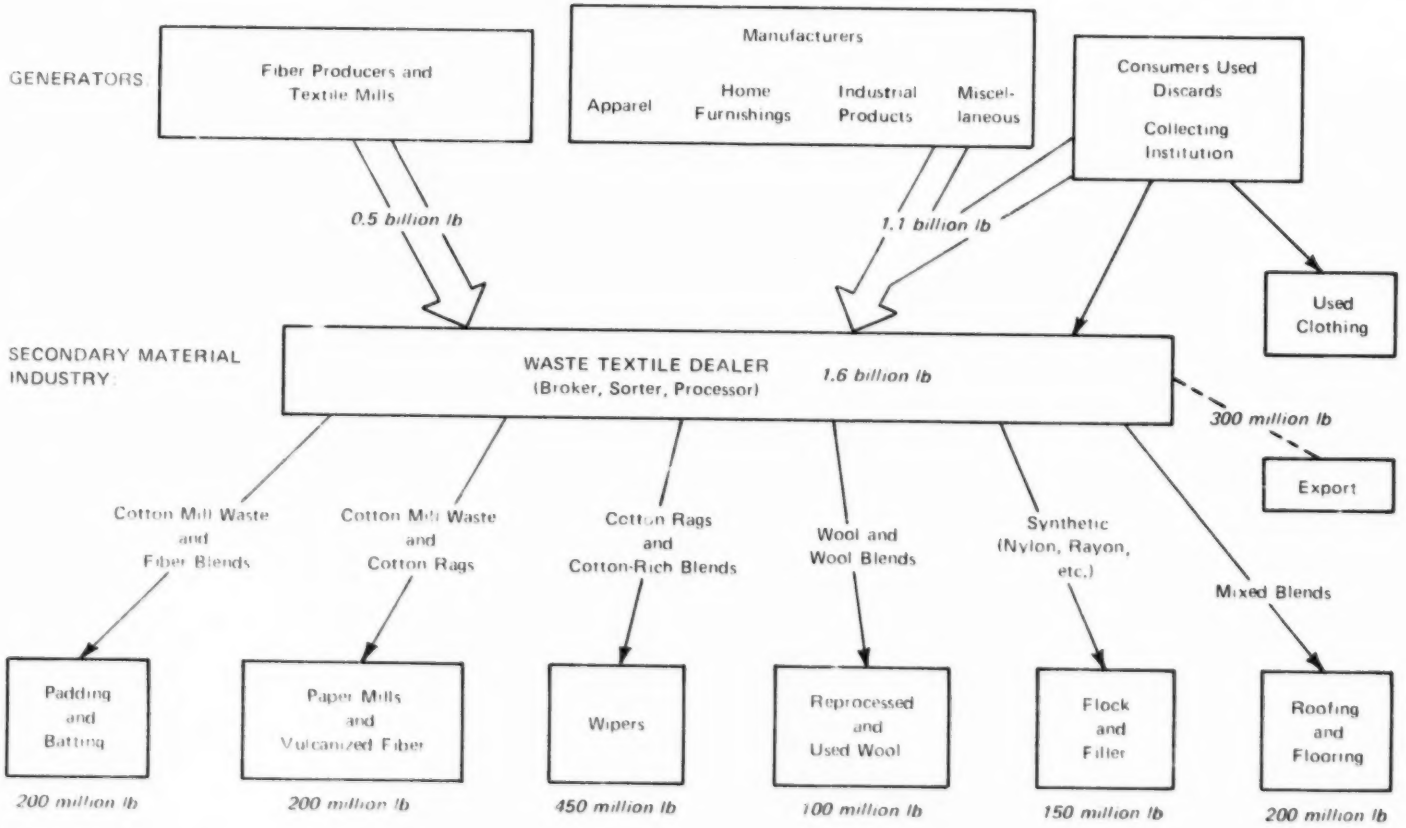


Figure A-9. Waste textile utilization flows.*

*Source: Battelle Memorial Institute, Columbus Laboratories, A study to identify opportunities for increased solid waste utilization, Book 3, v.9, U.S. Environmental Protection Agency, 1972. (Distributed by National Technical Information Service, Springfield, Va., as PB 212 731.)

# Resource Recovery Installations

## TABLE A-17

### MUNICIPAL SOLID WASTE COMPOSTING PLANTS IN THE UNITED STATES IN 1969*

| Location | Company | Process | Capacity (tons/day) | Type waste | Opening date | Status |
|---|---|---|---|---|---|---|
| Altoona, Pennsylvania | Altoona FAM, Inc. | Fairfield Hardy | 45 | Garbage, paper | 1951 | Operating |
| Boulder, Colorado | Harry Gorby | Windrow | 100 | Mixed refuse | 1965 | Operating intermittently |
| Gainesville, Florida | Gainesville Municipal Waste Conversion Authority | Metrowaste conversion | 150 | Mixed refuse, digested sludge | 1968 | Operating |
| Houston, Texas | Metropolitan Waste Conversion Corporation | Metrowaste conversion | 360 | Mixed refuse, raw sludge | 1966 | Operating |
| Houston, Texas | United Compost Services, Inc. | Snell | 300 | Mixed refuse | 1966 | Closed (1966) |
| Johnson City, Tennessee | U.S. Public Health Service and Tennessee Valley Authority | Windrow | 52 | Mixed refuse, raw sludge | 1967 | Operating |
| Largo, Florida | Peninsular Organics, Inc. | Metrowaste conversion | 50 | Mixed refuse, digested sludge | 1963 | Closed (1967) |
| Mobile, Alabama | City of Mobile | Windrow | 300 | Mixed refuse, digested sludge | 1966 | Operating intermittently |
| Norman, Oklahoma | International Disposal Corporation | Naturizer | 35 | Mixed refuse | 1959 | Closed (1964) |
| Phoenix, Arizona | Arizona Biochemical Company | Dano | 300 | Mixed refuse | 1963 | Closed (1965) |
| Sacramento County, California | Dano of America, Inc. | Dano | 40 | Mixed refuse | 1956 | Closed (1963) |
| San Fernando, California | International Disposal Corporation | Naturizer | 70 | Mixed refuse | 1963 | Closed (1964) |
| San Juan, Puerto Rico | Fairfield Engineering Company | Fairfield-Hardy | 150 | Mixed refuse | 1969 | Operating |
| Springfield, Massachusetts | Springfield Organic Fertilizer Company | Frazer-Ewson | 20 | Garbage | 1954 | Closed (1962) |
| St. Petersburg, Florida | Westinghouse Corporation | Naturizer | 105 | Mixed refuse | 1966 | Operating intermittently |
| Williamston, Michigan | City of Williamston | Riker | 4 | Garbage, raw sludge, corncobs | 1966 | Closed (1967) |
| Wilmington, Ohio | Good Riddance, Inc. | Windrow | 20 | Mixed refuse | 1963 | Closed (1965) |

*Source: Breidenbach, A. W. Composting of municipal solid wastes in the United States. Washington, U.S. Government Printing Office, 1971.

## TABLE A-18

RESOURCE RECOVERY INSTALLATIONS: INCINERATORS WITH MAJOR HEAT RECOVERY OPERATIONS*

| Location | Type of installation | Design refuse capacity (tons per day) |
|---|---|---|
| Atlanta, Georgia | Volund | 700 |
| Boston, Massachusetts | Refractory | --- |
| Braintree, Massachusetts | Waterwall | 240 |
| Chicago, Illinois (Northwest) | Waterwall | 1,600 |
| Chicago, Illinois (Southwest) | Refractory | 1,200 |
| Hempstead, New York (Merrick) | Refractory | --- |
| Hempstead, New York (Oceanside) | Refractory | 600 |
| Miami, Florida | Refractory | 900 |
| Norfolk, Virginia (U.S. Naval Station) | Waterwall | 360 |
| Oyster Bay, New York | Refractory | --- |
| Providence, Rhode Island | Refractory | --- |

*Source: Systems study of air pollution from municipal incineration, 3 v. Cambridge, Arthur D. Little, Inc., Mar. 1970. 920 p. (Distributed by National Technical Information Service, Springfield, Va., as PB 192 378 to PB 192 380.)

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